Understanding children's physical activity from a multilevel perspective in both a UK and international sample

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PUBLICATIONS

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Wilkie H, Standage M, Sherar L, Cumming S, Parnell C, Davis A, Foster C, Jago R. Results from England's 2016 Report Card on physical activity for children and youth. *J Phys Act Health.* 2016;13(11)(suppl 2):S143-S149. doi: 10.1123/jpah.2016-0298.

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Wilkie HJ, Standage M, Gillison FB, Cumming SP, Katzmarzyk PT. Correlates of children's physical activity outside of school hours: results from ISCOLE-UK. *BMC Public Health.*

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Forthcoming submissions:

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LIST OF ABBREVIATIONS

BMI	Body mass index
FFQ	Food Frequency Questionnaire
GCSE	General Certificate of Secondary Education
HBSC	Health Behaviour in School Aged Children Study
HIC	High income countries
HSE	Health Survey for England
ISCOLE	International Study of Childhood Obesity, Lifestyle and the Environment
LIC	Low income countries
LPA	Light intensity physical activity
MCS	Millennium Cohort Study
MPA	Moderate intensity physical activity
MVPA	Moderate-to-vigorous intensity physical activity
NTS	National Travel Survey
PA	Physical activity
PE	Physical Education
SES	Socioeconomic status
ST	Screen time
TPS	Taking Part Survey
UK	United Kingdom
US	United States
VPA	Vigorous intensity physical activity
WHO	World Health Organization
YST	Youth Sport Trust

ABSTRACT

Globally, childhood obesity is a severe public health concern. Thus, it is imperative to gain a deeper understanding of how to target modifiable lifestyle behaviours in order to curb the prevalence of obesity among youth. Physical inactivity in particular has been identified as the fourth leading risk factor for global mortality by the World Health Organization. The aim of this research was to explore correlates of objectively assessed physical activity (PA) using a socio-ecological approach in order to gain a broader understanding of how to promote activity levels, and in turn a healthy body weight, among children.

Data from the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE)[1] were analysed and six original empirical papers were produced. The first of these showed the importance of PA, as a negative relationship with overweight/obesity was found, independent of other behaviours. A literature review was then conducted, using a unique 'Report Card' assessment tool, to gauge the current 'state of the nation' in regards to children's PA. This work showed that few children are sufficiently active and several areas for future research were highlighted, which informed subsequent analyses. A number of correlates of PA were identified in the following two papers; outdoor time in particular was positively associated with most outcomes. Yet, it was recognized in the Report Card that time spent outdoors appears to have declined, thus correlates of this behaviour were explored in the penultimate paper, which showed that certain groups may need to be targeted. Inconsistent findings were reported across all papers regarding the role of screen time, thus this formed the primary focus of the final paper. Screen time may compete with PA among particular groups depending on the screen-based behaviour in question.

Overall, this body of research has contributed to the extant literature, and the findings support the need for further work involving context-specific analyses.

CHAPTER 1

General Introduction

1.1 Overview

Six empirical papers have been produced to address several original research questions pertaining to children's physical activity (PA) participation. As each empirical contribution includes an Introduction section, the purpose of this chapter is to introduce the overarching background literature which has informed the rationale and objectives of these empirical papers. First, an overview of childhood obesity and the importance of PA is provided. Second, an introduction to the socio-ecological model which has been used throughout is presented. The specific research questions that are addressed in this thesis are proposed based on gaps in the literature and areas that require further work. Third, an outline of the systematic programme of research that has been conducted is included, encompassing a brief description on what each Chapter entails, including a brief introduction to the methodology that has been employed.

1.2 Childhood Obesity

The global prevalence of childhood overweight and obesity increased by 47.1% from 1980 to 2013 according to a systematic analysis of worldwide health surveys.[2] However, it is promising that the rates of obesity have appeared to slow down in developed countries over the past decade.[2,3] Despite this, prevalence estimates of childhood obesity are still at unprecedented levels and a decline in the incidence of overweight and obesity is yet to be seen in most developed countries including the United Kingdom (UK).[3] Latest figures from the National Child Measurement Programme show that 34.2% of children in Year 6 (age 10-11) are classified as overweight or obese across England, which is the highest reported percentage since the programme began in 2006.[4] It is therefore not surprising that childhood obesity is now recognised as one of the most severe public health concerns of our time,[5,6] given its associated health risks, including type 2 diabetes and clustered metabolic risk factors for cardiovascular disease.[7-9]

Obesity during childhood is likely to have health implications in later life given evidence that tracking of childhood obesity into adolescence and subsequently

aduthood can occur,[10] and a high body mass index (BMI) in childhood was associated with diabetes, coronary heart disease and even some cancers during adulthood[11] according to two recent meta-analyses.[10,11] Although targeting childhood obesity will not necessarily combat the over-riding issue of obesity related ill-health observed in adults however (since a large proportion of obese adults were actually a healthy weight as children[10]), it is important to account for the immediate physical and psychological health risks posed to those suffering from obesity at a young age.[10,11] For example, in addition to physiological health risks, obese children and adolescents may also suffer from negative psychological and social consequences including stigmatization, anxiety, depression, and low self-esteem.[8,12-14] Childhood obesity has even been associated with lower academic achievement among girls,[15] thus there are huge benefits to be gleaned by tackling this health concern during childhood. Furthermore, early intervention may help to establish healthy lifestyle habits from a young age, and there is wide consensus that prevention is essential if we are to observe a decline in current childhood obesity levels.[8,16,17] In order to achieve the most effective means of prevention, it is important to understand the causes of childhood obesity so that suitable interventions can be designed and implemented appropriately.

1.3 Understanding the Development of Childhood Obesity and the Role of Modifiable Lifestyle Behaviours

Past work has shown that childhood obesity is the result of a complex interaction of multiple biological and environmental factors, all of which operate at several levels of influence.[18] As such, socio-ecological models that take multiple factors into account are recommended as they can be used to provide a deeper understanding of how to change behaviour.[18,19] However, an important first step is to understand which behaviours ought to be targeted.

It is widely accepted that globalization, technological developments, and societal changes over several decades have led to increasingly sedentary lifestyles as well as unhealthy eating practices.[5,16] In turn, this has contributed to the global childhood obesity crisis,[5,16] given that obesity arises from an energy imbalance (i.e., energy intake exceeds energy expenditure).[8] Thus, modifiable lifestyle behaviours such as PA and dietary patterns are obvious targets,[8] and the impact of these as well as sedentary behaviours (e.g., TV viewing) on overweight/obesity has been widely assessed in previous research (e.g.,[20-26]). There is also growing evidence that sleep

duration may have a role to play in the development of childhood obesity,[27-29] and each of these lifestyle behaviours likely interact with one another. For example, children who watch lots of TV may be consuming more energy dense foods while engaging in such behaviour,[30] or TV viewing may displace PA, but support for the latter is lacking.[31] The effects of sleep duration are also likely to be indirect via an increased appetite or lack of PA.[32] Such mechanisms highlight the importance of exploring how these behaviours interact to influence body weight, because this information can be used in future interventions, designed to modify multiple lifestyle behaviours.[32] However, there is a lack of research exploring the role of all four behaviours simultaneously, on adiposity status among children in the UK; in particular, sleep duration is rarely considered. Consequently, the first empirical chapter of this thesis (Chapter 2) sought to address this gap in the literature; both the independent and interacting effects of these behaviours on body weight were explored in a UK sample of children.

1.4 The Importance of Physical Activity

Despite the lack of research on all four lifestyle behaviours on childhood obesity in the UK, it is evident from past work that moderate-to-vigorous intensity PA (MVPA) is likely to be particularly important for the maintenance of a healthy weight.[22,33-38] PA is also essential for healthy physiological and psychological development given that it promotes physical, mental and social well-being.[39] For example, other benefits include enhanced cardio-respiratory fitness,[40] improved bone health,[41] more developed motor competencies,[42,43] lower risk of depressive symptoms,[44,45] and reduced clustered cardiovascular risk.[37,46] PA may even prevent some cancers in later life.[47] It is therefore important for individuals to adopt an active lifestyle from a young age, particularly since there is evidence to suggest that activity habits adopted during childhood and adolescence can transfer into adulthood.[48,49]

However, there appears to have been a global decline in PA levels,[50] and the World Health Organization (WHO) has recognised this to be one of the leading risk factors for mortality across the world.[51] In England, only 21% of boys and 16% of girls (age 5-15 years) achieved sufficient amounts of PA on a daily basis, according to the Health Survey for England (HSE).[52] These recommendations state that 5-18 year olds should be engaging in at least 60 minutes of MVPA per day.[53] Furthermore, a large proportion of the day appears to be spent in sedentary pursuits,[54-56] and less than half of 5-16 year olds in England actively commute to and from school.[57]

Consequently, there is a need to understand why PA levels are low and how best to tackle this complex issue. The primary focus of this thesis therefore, was to gain a deeper understanding of PA behaviour specifically. It is hoped that this research can be used to inform future policy directions and interventions which aim to promote increased PA among children, and in turn prevent further increases in childhood obesity levels.

1.5 A Socio-Ecological Model of Physical Activity

Participation in PA is also complex as it can be influenced by a multitude of factors and consists of a variety of behaviours which can be done in a number of settings.[19] For example, children spend the majority of their time at school, thus the school environment provides an important influential setting,[58,59] whereas participation in PA outside of school is likely to interact with the home environment.[60] It is therefore worthwhile studying PA from a multilevel perspective too using a socio-ecological model, such as that developed by Sallis and colleagues,[19] which takes several behaviours and levels of influence into consideration.

In this model, PA is categorised into four domains of 'active living', including active transport, active recreation, household and occupational activities. Within each of these domains, there are several intra- and inter-personal factors (e.g., demographic, biological, psychological, social and environmental influences) that can influence PA engagement.[19] In children specifically, PA is likely to be attained through active play, active transport, organised activity (e.g., dance classes and sports teams) and domestic activity (i.e., household chores), which all take place in different settings including the school, home or neighbourhood environments.[39] The socio-ecological model also includes numerous policies and investment strategies that can be implemented by schools, local authorities and the government.[19] Altogether, this demonstrates the complexity of research in this area, as PA undertaken by children can be influenced by different people (e.g., parents, teachers and peers), environments, settings and policies. The model will therefore be used in this thesis to explore multiple levels of influence, by taking into account potential individual, home, neighbourhood and school level factors rather than focussing on one or two levels only, as frequently has been the case in past research (e.g.,[59-62]). It is hoped that this will provide a comprehensive, more holistic, picture of the environments and factors within these that can promote PA among children.

Sallis and colleagues[19] have argued that the socio-ecological model can be used to improve intervention design and enhance efforts to increase PA levels among children and youth. Hearst et al,[63] stated that factors from multiple levels are inter-related, and the socio-ecological model illustrates the important role that they play in terms of influencing PA participation. However, a key criticism of this model is its purely descriptive nature. It is essentially a list of potential influences within different settings for different means of PA; it currently provides no information on how such factors interact and relate to eachother, nor how specific factors differ according to demographic characteristics. Despite this, Sallis and his colleagues[19] do call for more research testing such mechanisms, and it is recognised that focussing on one specific environment can offer the opportunity to explore specific relationships and mechanisms at play more closely. As such, although PA is explored more widely to begin with, ultimately a deeper, more narrowed and refined focus on some mechanisms are explored towards the end of this thesis.

1.6 Correlates of Physical Activity

Identifying correlates of PA will help to determine how PA can be accrued. Several reviews have examined studies exploring the correlates of PA among children and adolescents, using the socio-ecological model, and a review of reviews was recently conducted by both Sterdt et al[64] and Biddle and colleagues.[65] These were based on reviews that explored cross-sectional studies but another review by Bauman et al[66] included longitudinal data. The fact that more than one review of reviews has been conducted demonstrates the plethora of research that is currently available on the correlates of PA among children and youth.

Yet, with the exception of age and gender, results have largely been inconsistent,[65] the majority of research has been conducted in the United States (US) and self-reported measures of PA have predominantly been employed.[64] The varying results between studies are likely a result of differences in the samples and methodology,[64] but past work has been criticised because there has been a lack of specificity in the research being carried out.[65] For example, general measures of PA (e.g., total PA performed across the week) tend to be measured.[65,67] Although analysing PA in this way can identify important correlates associated with overall PA levels achieved throughout a typical week, this could result in important underlying relationships being missed as it does not allow researchers to understand correlates associated with specific behaviours, intensities, or PA performed during specific times.[65,67] For

example, studies have repeatedly shown that boys have higher PA levels than girls.[52,54,68-72] Thus, gender is the most consistently reported correlate of PA in the literature.[64-66] However, it is possible that relationships differ according to specific PA behaviours, such as sports participation, active transport and active play,[65] and there may be particular times when the gap widens (e.g., during or outside of school time).

Results from the HSE (2012) supported this notion because the gender gap was not apparent for active travel to school,[52] and it has previously been suggested that active transport may provide a suitable avenue for promoting PA among some girls because it could be more appealing and accessible than sport for example.[73] However, for those who use passive forms of transport, certain barriers may be influencing their current behaviour. With the socio-ecological model in mind, these could include traffic-related safety concerns, trip length, and walkability or it may be a matter of convenience.[19] Alternatively, there could be a lack of facilities at schools which cater for active transport (e.g., no parking sites for bicycles).[19] Consequently, research which examines a variety of potential correlates from a wide range of settings (e.g., both schools and parents) is likely to provide more detailed and refined information on the most important barriers or facilitators that need changing.

In addition, certain intervention strategies may be more effective among some children and less so for others, and may depend on the context in question. For instance, correlates related to parental and home environment influences are likely to be more important at specific times, as they were found to be more relevant to the after school period than the weekend in a study of 9-10 year olds.[60] It was speculated that other factors away from home are likely to be more influential on weekends.[60] In addition, parental support and parental PA were positively associated with children's PA in a review,[74] though parental PA was only significant in boys, which would suggest that important gender interactions are also taking place. Moreover, a father's PA level may be more influential than a mother's,[65] thus numerous factors are at play which further demonstrates the complexity of research in this area.

Delving further into specific relationships will provide a deeper understanding, and such information would enable researchers to design interventions that utilise a more targeted approach. This is particularly important because past interventions designed to prevent childhood obesity (by targeting dietary and/or PA behaviour)

have had significant but generally small favourable effects.[75] It has been argued that new, innovative approaches that combine multiple settings, including both school and home environments are needed.[75] Overall, these issues call for more detailed research whereby different types of PA performed during specific times are considered as well as differences between subgroups. Therefore, the aim of this thesis was to explore correlates associated with intensity-, time- and behaviour-specific PA and ultimately to make comparisons between subgroups.

1.7 Thesis Outline

In summary, the primary aim of this thesis was to gain a deeper understanding of PA behaviour in UK children using a multilevel framework based on the socio-ecological model provided by Sallis and colleagues.[19] Six empirical papers were produced to address the following research questions:

I. Is PA associated with lower odds of overweight and obesity independent of other lifestyle behaviours in a sample of UK children and how do such behaviours interact to influence body weight?

This question was addressed in Chapter 2. Associations between multiple lifestyle behaviours (PA, screen time (ST), dietary patterns and sleep duration) and overweight/obesity were assessed. Interactions between these behaviours and their relationship with BMI were also explored.

II. What is the current 'state of the nation' in terms of PA levels among children and youth in England, and how are we doing as a country to promote PA participation at different levels of influence (i.e., school, policy etc.)?

A review of the literature was conducted to examine current levels of PA participation among children and youth across England (Chapter 3). Following the Active Healthy Kids Canada Report Card model,[76] five PA behaviours and four levels of influence were assessed in order to answer question 2. The findings of this work provide an update to the Active Healthy Kids England 2014 Report Card on PA for children and youth.[77]

III. What are the correlates of intensity-specific PA and which correlates are associated with meeting the MVPA guidelines, according to the socio-ecological model?

Correlates of intensity-specific PA (light, moderate, and vigorous) and factors associated with meeting the MVPA guidelines were assessed in Chapter 4. Potential correlates were carefully chosen akin with results of previous research. In particular, those which tend to have inconsistent associations with PA that require further study were analysed. Correlates from multiple levels aligned with the socio-ecological model were explored in order to provide a more comprehensive understanding of correlates that promote PA among children.

IV. What are the correlates of PA performed outside of school using the socio-ecological model?

Similar to Chapter 4, correlates of MVPA outside of school time specifically (before school, after school, and during the weekend) were assessed using the socio-ecological model in Chapter 5. The results from Chapters 3-5 helped to inform the objectives of the following two Chapters, for which a more detailed perspective on specific relationships was sought, including differences between subgroups.

V. Are parental perceived safety concerns and time spent in screen-based pursuits associated with less time spent outdoors?

Time spent outdoors was positively associated with PA in both Chapters 4 and 5, yet in the literature review conducted for Chapter 3, it was evident that children appear to have little freedom to roam due to heightened parental safety concerns. Furthermore, it was apparent that children may be spending a lot of time indoors on screen-based pursuits instead. Thus, the purpose of Chapter 6 was to assess the relationships between the home electronic media environment and parental safety concerns on outdoor time. Interactions with sex and socioeconomic status (SES) were analysed in order to further our understanding of how such relationships differ according to these subgroups.

VI. How do associations between screen-based behaviours and objectively assessed PA differ by sex and SES?

Given a lack of consistency with regards to the relationship between sedentary behaviour and PA in the literature, the purpose of Chapter 7 was to test the ‘displacement hypothesis’ from a more detailed perspective.

Finally, a general discussion is provided in Chapter 8, in which a summary of the key findings is presented. Strengths and limitations of the current research are

discussed, particularly in relation to the methodology employed, as are the practical implications of the research findings, and ultimately, future research directions are proposed.

1.8 An Introduction to the Methodology and Some Considerations

1.8.1 The International Study of Childhood Obesity, Lifestyle and the Environment

Data from the International Study of Childhood Obesity, Lifestyle and the Environment (ISCOLE)[1] were analysed throughout this thesis to systematically address the research questions proposed in Chapters 2 and 4-7, via five original peer-review contributions. The ISCOLE study involved the collaboration of 12 study sites spanning five geographic regions (Europe, South East Asia, Africa, the Americas, and Western Pacific).[1] Participating countries included Australia (Adelaide), Brazil (São Paulo), Canada (Ottawa), China (Tianjin), Colombia (Bogotá), Finland (Helsinki, Espoo and Vantaa), India (Bangalore), Kenya (Nairobi), Portugal (Porto), South Africa (Cape Town), the UK (Bath and North East Somerset), and the US (Baton Rouge).[1] The methodology used for this study is described in detail elsewhere, which includes information about all 12 countries.[1] However, with the exception of Chapter 7, in which data from all 12 countries were analysed, this thesis utilised data from the UK site specifically. Although a methods section has also been provided in each empirical Chapter, a brief summary of the methods in relation to the UK site, as well as some methodological considerations, are outlined below.

1.8.2 The Sample

Children aged 9-11 years old within Years 5 and 6 were recruited from schools across the Bath and North East Somerset and West Wiltshire regions. Schools were stratified according to size and an indicator of SES (the proportion of pupils eligible for free school meals), in order to increase the variability of SES within the UK site.[1] Informed parental consent and child assent were obtained prior to data collection, and ethical approval was granted from the Research Ethics Approval Committee for Health (REACH) at the University of Bath.

1.8.3 The Study Protocol

Data collection took place across term time, from September 2011 to January 2013, by trained ISCOLE staff. This involved a visit to the participating school, whereby anthropometric measurements were taken and participants completed a Diet and Lifestyle Questionnaire (see Appendix 1). Two questionnaires were then sent home with the children for their parents to complete. These consisted of a Demographic and Health Questionnaire, and a Neighbourhood and Home Environment Questionnaire (see Appendices 2 and 3). The children were also given an accelerometer to wear for 7 days, plus an initial familiarisation day, which was returned along with the parental questionnaires the following week during a second visit to the school. A School Environment Questionnaire (see Appendix 4) was also completed by an administrator from each participating school and a school audit was undertaken by two trained ISCOLE staff members, in order to gain information on the school environment as well. With the exception of the school audit tool, data from each of these measures have been used in this thesis. Each questionnaire included items adapted from previous studies and validated sources,[78-92] and some items were developed by the ISCOLE team (cf.[1]). More information on these measurements has been provided within each Chapter according to the variables of interest, and a detailed overview of the methodology employed across the whole ISCOLE study has been published elsewhere.[1]

1.8.4 Statistical Analysis

As participants were recruited from schools, children within the same school are likely to share similar characteristics. As such, it is important to control for these potential clustering effects using linear mixed modelling procedures, given that the assumption of independent observations would be violated with ordinary least squares regression.[93] The Intra-Class Correlation (ICC) provides the amount of variation that exists in an outcome variable at both the individual and school levels, thus the ICC was computed for all empirical chapters. It has been argued that multilevel modelling procedures are not required with a small ICC, less than 0.05 for example (i.e., < 5% of the variability in the dependent variable at the school level),[94] but it is also recommended that school clustering should be accounted for if the study design and data collection warrants it.[95] Therefore, schools were treated as random effects in all empirical chapters because of the study design (i.e., data were collected on children nested within schools), using the PROC MIXED and PROC

GLIMMIX procedures for continuous and categorical outcome variables, respectively, within SAS Studio version 3.5 (SAS Institute Inc., Cary, NC, USA, 2012-2016).

1.8.5 Sample Size

It was calculated that a minimum sample size of at least 350 participants within each ISCOLE site would provide sufficient power (> 90% at the 5% significance level) to detect a significant difference in BMI from objectively assessed PA.[1] However, a target sample size of at least 500 children across a minimum of 20 schools was set, given the potential clustering effect of schools and loss of participants due to missing data.[1] In the UK, consent forms were distributed to 1114 children, and data from a total of 525 children deemed eligible to participate were collected. With the sample size requirements in mind, results were presented for the total sample in all Chapters that utilised UK only data (i.e., Chapters 2, and 4-6), given that there would likely be insufficient power to detect significant relationships if stratified by demographic characteristics (e.g., by sex). In order to explore differences by sex and SES in Chapter 6, interactions with these variables were assessed, and in Chapter 7, data from the entire ISCOLE study including all 12 countries were analysed.

CHAPTER 2

Multiple lifestyle behaviours and overweight and obesity among children aged 9-11 years: results from the UK site of the International Study of Childhood Obesity, Lifestyle and the Environment

Chapter 2 Opening Commentary

In this thesis, the first empirical chapter sought to explore whether PA was associated with a lower risk of overweight and obesity among participants of the UK ISCOLE study (cf.[1]). In order to extend the extant literature in this area, other lifestyle behaviours (ST, sleep duration and dietary patterns) were also analysed given the lack of research exploring all four behaviours simultaneously within a given sample of UK children.

Given that interactions between lifestyle behaviours have rarely been explored in past work, a second objective of the work presented within this chapter was to test interactions among these behaviours and how they relate to BMI z-score. All four behaviours were categorised according to government behavioural recommendations so as to enhance the applicability of the findings. This enabled us to explore differences in BMI z-score between groups of children who achieve these guidelines and those who do not.

Statement of Authorship

This declaration concerns the article entitled:									
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Candidate's contribution to the paper (detailed, and also given as a percentage).	**Formulation of ideas:** The candidate contributed considerably to the ideas for analysis used in this paper. Candidate contribution = 80% **Design of methodology:** The candidate did not contribute to the study design or methodology employed in the overall ISCOLE study. The candidate did select the variables of interest included in the analysis as well as the analytic methods employed in the paper. Candidate contribution = 30% **Experimental work:** The candidate did not collect data until the closing stages of the ISCOLE study. The candidate conducted all statistical analyses for this paper, with the exception of the PCA for diet, and the algorithm used to detect sleep (references have been provided for these components). Candidate contribution = 55% **Presentation of data in journal format:** The candidate created a draft manuscript and formatted it in accordance with journal submission requirements. Remaining authors provided edits, comments and contributions to the paper. Candidate contribution = 85%								
Statement from Candidate	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature.								
Signed						**Date**	25/07/2017		

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Data access statement: No additional data are available.

2.1 Abstract

Objectives: The purpose of this study was to explore the independent associations between multiple lifestyle behaviours (PA, sleep, ST and diet) and overweight and obesity in UK children. A second objective was to compare BMI z-score between children who meet health guidelines for each lifestyle behaviour and those who do not, and to explore the impact of interactions between lifestyle behaviours on BMI z-score.

Design, Setting and Participants: Cross-sectional study on 9-11 year olds in the UK (n=374).

Outcome Measures: Participants were classified as overweight or obese using the WHO BMI cut-points. MVPA and sleep duration were measured using an ActiGraph GT3X+ accelerometer, whereas ST and dietary habits were assessed using questionnaires. Multilevel multiple logistic regression was employed to analyse associations between lifestyle behaviours and overweight/obesity. Participants were then categorised according to whether or not they met specific health criteria for MVPA, ST, sleep and diet. Multilevel multiple linear regression was used to compare these groupings on the outcome of BMI z-score and interactions were explored.

Results: MVPA and longer sleep duration were associated with lower odds of overweight or obesity, whereas ST and a healthy diet score were associated with increased odds of overweight/obesity. No association was found for an unhealthy diet score. Meeting MVPA guidelines was significantly associated with a lower BMI z-score in all models, and significant two-way interactions were observed for PA and sleep, ST and sleep, and PA and diet.

Conclusions: MVPA, sleep and ST are important lifestyle behaviours associated with overweight/obesity among children. More research is required to confirm the role of diet on adiposity and such work would benefit from objective assessment. Overall, this work suggests that strategies aimed at improving compliance with health guidelines are needed.

2.2 Strengths and Limitations of this Study

- The role of four lifestyle behaviours (PA, sleep, ST and diet) on overweight/obesity has been assessed, thereby adding to the existing literature on adiposity among UK children.

- The study is limited by its cross-sectional design and predominantly white British participant group, thus inferences about the direction of causality cannot be made and the results may not generalise to other ethnic groups.
- Although PA and a proximal indicator of sleep were measured using accelerometry, self-reported measures were employed to assess ST and diet, a method that is subject to social desirability and recall bias.

2.3 Introduction

Childhood obesity presents a number of immediate and long-term health risks,[1] including several adverse physiological[2,3] and psychological health consequences.[4] Across the world, the prevalence of childhood overweight and obesity is high.[5] In England, a third (33.5%) of 10-11 year old children are classified as overweight or obese.[6]

PA, sleep, ST (e.g., TV viewing) and eating habits are four key modifiable lifestyle behaviours that can influence body weight. For example, PA may protect against adiposity among children,[7-9] whereas a lack of sleep,[10-12] TV viewing,[7,13-16] and the consumption of sugar-sweetened beverages[9,17,18] are potential risk factors for obesity. Mixed findings have been reported for other dietary behaviours, particularly for those considered to be 'healthy' (e.g., fruits and vegetables).[18] In a recent UK study, for example, Basterfield et al,[19] reported no significant dietary influence on overweight or obesity when a 'healthy' diet was compared to an 'unhealthy' diet, despite participants completing a food diary. Conversely, achieving a sufficient level of MVPA was associated with lower odds of overweight/obesity, though this relationship was only present among boys. However, caution was noted in regard to this finding due to the small number of active female participants.[19]

It is important to explore multiple lifestyle behaviours that influence childhood overweight and obesity so that future interventions and policies can be developed appropriately.[20] Yet, research on UK children whereby all four lifestyle behaviours have been examined simultaneously within the same sample of participants is distinctly lacking. For example, neither ST nor sleep duration were assessed in the UK study conducted by Basterfield et al,[19] and the majority of research on the role of sleep has been conducted outside of the UK.[21,22] A recently published paper from the ISCOLE study reported TV viewing, sleep duration and MVPA to be independently associated with obesity.[15] Data from the 12 participating countries,

including the UK, were presented. Using a similar analytical approach to that of Katzmarzyk et al,[15] we sought to examine the effect of lifestyle behaviours on the likelihood of overweight and obesity among UK participants only.

Furthermore, exploring how lifestyle behaviours interact to influence markers of health could aid our understanding of where and how we should try to intervene.[23] As such, a second objective was to explore interactive effects of lifestyle behaviours on BMI z-score, by comparing the outcome variable (BMI z-score) between children who achieved government recommended behavioural standards for health and those who did not.

2.4 Methods

2.4.1 Participants

Data were analysed on UK children who participated in the ISCOLE study. A detailed description of the ISCOLE design, methods and power analysis has been provided elsewhere.[24] Children aged 9-11 years were the target population[24]; thus primary school pupils in Years 5 and 6 were recruited. A cross-sectional study design was employed which involved collecting a series of objective and subjective measures throughout term time. Data were collected across a total of 26 schools within Bath and North East Somerset and West Wiltshire from September 2011 to January 2013. Participants were included in the current study if they were aged between 9 and 11 years and provided complete data for all measures, including covariates. Informed parental consent and child assent were obtained for each participant. The study was approved by a University of Bath ethics committee.

2.4.2 Measures

2.4.2.1. Anthropometry

A series of anthropometric measurements were obtained from participants using standardised procedures by trained ISCOLE staff.[24] BMI, calculated from body mass (kg) divided by height (m^2), was used to define obesity. Participants' body mass was measured using a portable Tanita SC-240 Body Composition Analyser (TANITA Corporation, Tokyo, Japan) and their stature with a Seca 213 portable stadiometer (Hamburg, Germany).[24] Measures were repeated twice, and the average was calculated for analysis.[24] A third measurement for height or weight was performed if the difference between the first two was larger than 0.5 cm or 0.5 kg,

respectively, and the average of the closest two measurements was computed.[24] Participants' BMI z-score was derived from the WHO growth reference data,[25] and participants were classified as overweight/obese if their score was >+1SD.[25] All other participants were categorised as not overweight/obese.

2.4.2.2. Accelerometry

Participants were asked to wear an ActiGraph GT3X+ accelerometer (ActiGraph, Pensacola, Florida) attached to an elastic belt around their waist.[24] They were encouraged to wear it at all times, except for during water-based activities, for one week. This allowed for daily PA to be recorded, and this protocol has been shown to provide acceptably reliable estimates of most accelerometer-derived metrics.[26] Time spent in MVPA was analysed in this study as this intensity of activity directly aligns with the UK PA guidelines[27] and because MVPA has been negatively associated with adiposity as opposed to light-intensity activity previously.[28] MVPA was determined using the Evenson cut-points (≥ 574 counts per 15 seconds),[29] which are appropriate and valid for use in children.[30] Participants were considered eligible for analysis if they had accelerometry data for at least four days, including one weekend day and a minimum of 10 hours wear time per day; any period of 0 activity counts lasting at least 20 consecutive minutes was classified as non-wear.[31]

Accelerometry can also be used to provide a proximal indicator of sleep duration. Using the protocol developed via the ISCOLE study,[32] nocturnal sleep duration was quantified using a published automated algorithm.[33] Briefly, total sleep duration was estimated using the total minutes from all nocturnal sleep episodes, identified using a combination of the Sadeh algorithm[34] and the inclinometer function to determine the probability of sleep for each individual minute.[33] Lastly, mean time spent sleeping per night across the week was computed for those with at least three nights of data, including one weekend night. All accelerometry data were managed in SAS (version 9.3).

2.4.2.3. Self-reported Measures

Using 24-hour accelerometry data for MVPA, sleep and sedentary time would result in substantial collinearity.[35] As there are advantages to having more specific indicators of sedentary time use, particularly in relation to the degree to which such behaviours could be influenced (e.g., travel, study time, screen use), we chose to analyse self-reported sedentary behaviour via a questionnaire to reduce the issue of

collinearity. We sought to examine the role of overall ST, in terms of both TV viewing and computer use, in order to capture children's engagement in more than one screen-based behaviour. ISCOLE staff were trained on how to deliver the questionnaire, including how to respond to participant questions in a standardised manner in order to reduce bias.[24] Participants were asked how many hours they had watched TV on a school and weekend day in the last week. They could choose from seven options, coded as: I did not watch TV on school/weekend days (0); less than 1 hour (0.5); 1 hour (1); 2 hours (2); 3 hours (3); 4 hours (4); 5 or more hours (5). The equivalent was asked for how often they played video/computer games or used a computer that was not for school work, as leisure time screen use better reflects a lifestyle choice over computer use for school work. These items were taken from the US Youth Risk Behavior Surveillance System,[36] which has been deemed as a valid and reliable tool for assessing TV viewing and computer use.[37] Overall ST score was computed by summing the TV and computer scores, which were calculated using weighted averages to account for school and weekend ST.

Questions pertaining to participants' dietary habits were adapted from the Food Frequency Questionnaire (FFQ) for the Health Behaviour in School-Aged Children (HBSC) Study.[38] There were 23 items in total, comprising a selection of foods. For each food group, participants responded how often they eat each item in a typical week: never; less than once a week; once a week; 2-4 days a week; 5-6 days a week; once a day, every day; and every day, more than once. This FFQ is considered to have acceptable reliability and validity for assessing food consumption among 9-11 year olds.[39] Using the data from the FFQ, principal components analysis (PCA) was employed to identify dietary patterns among the sample, which has been described elsewhere.[40] Within this paper, Mikkilä and colleagues[40] identified two dietary patterns, which were termed 'healthy' and 'unhealthy' based on the food groups that loaded onto these two components (e.g., vegetables, fruits and berries etc., and fast foods, ice cream, sugar-sweetened beverages etc., respectively). Scores were standardised, thus a higher 'healthy' diet score represents a healthier diet, whereas a higher 'unhealthy' diet score represents a less healthy diet.

2.4.2.4. Demographic Variables

Information regarding the age and sex of participants was provided by the child's parent or guardian. Data were also obtained from parents/guardians on their highest

level of education attained, which was used as an indicator of SES. Participants were categorised into one of three groups based on whether their parents/guardians had achieved a low (General Certificate of Secondary Education (GCSE) or less), medium (A Levels or equivalent) or high (University degree) education. Where data were available for both parents with different education levels, the parent with the highest education level was used.

2.4.3 Data Handling

To facilitate the testing of our second objective (i.e., to compare BMI z-score between children who meet specific health standards for lifestyle behaviours and those who do not), participants were categorised for each behaviour based on the following criteria: 'active' children recorded a mean of 60 minutes MVPA per day[27]; 'long sleepers' were achieving enough sleep based on specific recommendations for their age group (age 9: ≥ 10 hours; age 10: ≥ 9.75 hours; age 11: ≥ 9.5 hours)[41]; 'low ST' users achieved a mean ST score of ≤ 2.0 hours/day.[42] Those not meeting these guidelines were classified as 'inactive', 'short sleepers' and 'high ST' users, respectively. A median split was used to differentiate healthy from unhealthy eaters, along the healthy and unhealthy dietary scores, derived from past work via the use of PCA.[40] This resulted in three groups for comparison: children with a healthy diet score above the median and an unhealthy diet score below the median were categorised as having a 'healthy diet' (n=100); children below the median for their healthy diet score and above the median for their unhealthy diet score were categorised as having an 'unhealthy diet' (n=100), and all other children (i.e., those above the median for both a healthy and unhealthy diet score or vice versa) were classified as displaying a 'mixed diet' (n=174). This method has been used previously,[19] and as there are numerous guidelines currently in place for different dietary behaviours,[43] we chose to adopt the same method for simplicity and comparability.

2.4.4 Statistical Analysis

Descriptive statistics were computed and compared between those included and excluded from the analysis, using independent t-tests for continuous variables and chi-square tests for categorical data. No significant interactions were found between the behavioural variables and age or sex, thus results are presented for the total sample. However, due to their potential confounding effects, all analyses were

adjusted for age, sex and SES. Relationships between lifestyle behaviours (MVPA, ST, sleep duration, a healthy diet score and unhealthy diet score) and overweight/obesity were examined using multilevel multiple logistic regression (PROC GLIMMIX), with schools treated as random effects in all models. In Model 1, relationships between each behaviour and overweight/obesity were assessed adjusting for potential covariates. In Model 2, all four behaviours and covariates were included simultaneously in order to obtain independent associations between each behaviour and overweight/obesity. For the second objective, BMI z-score was compared between groups (e.g., active versus inactive) using multilevel multiple linear regression (PROC MIXED), accounting for potential clustering within schools in all models. Age was centred at the grand mean so that all variables had a meaningful zero. In Model 1, simple relationships between the categorical variables and BMI z-score were conducted, adjusting for age, sex and SES. In Model 2, all categorical variables and covariates were included to produce a mutually adjusted model. Finally, all six possible two-way interactions between behavioural groups were added and any that were non-significant ($p>0.10$) were deleted in a stepwise manner, using the backward elimination approach until only significant interactions were left ($p<0.05$). The sample size of each group for all possible interactions was adequate for statistical analysis (i.e., > 5% of the total sample was present in each group) and tests were conducted to check there was no severe multicollinearity.[44,45] The least squares means of significant interactions were computed, and post-hoc tests using the Bonferroni correction were conducted, in order to identify which groupings were significantly different. Effect sizes of these differences were computed using Hedges' *g*. All analyses were conducted using SAS Studio, release 3.4 (SAS Institute Inc., Cary, NC, USA, 2012-2015).

2.5 Results

A total of 1114 consent forms were distributed and 541 participants provided consent, of whom 410 remained following eight withdrawals and excluding those without valid accelerometry data for both PA and sleep. Further excluding participants with missing data for SES resulted in an analytic sample of 374 participants. No significant differences were reported between those included or excluded for any of the exposure or outcome measures. Descriptive statistics for the analytic sample are displayed in Table 2.1. The mean age of participants was 10.9 (± 0.4) years, 42.8% of the analytic sample were boys, and 28.6% of the analytic sample were classified as overweight/obese. Approximately half of children were

classified as meeting the MVPA guidelines, whereas 32.1% and 40.4% of the total sample met the ST and sleep recommendations, respectively. The majority (77.5%) of participants obtained 7 valid days of accelerometer data, while 1.6%, 4.3% and 16.6% obtained 4, 5 and 6 valid days of data respectively.

The intraclass correlation revealed that approximately 2% of the variability in overweight/obesity and 3% for BMI z-score was accounted for by the school-level effect. Thus, 97-98% of the variability was accounted for by individual-level factors.

2.5.1 Lifestyle Behaviours and Overweight/Obesity[*]

Odds ratios for each lifestyle behaviour (measured as continuous variables) and overweight/obesity are displayed in Table 2.2. Higher MVPA and sleep duration were associated with lower odds of overweight or obesity in Model 1, adjusting for potential covariates (age, sex and SES). Conversely, a higher ST was associated with higher odds of overweight/obesity. No significant relationship was observed for either dietary score. Results from Model 2, in which all lifestyle behaviours were entered simultaneously, were similar in that MVPA, sleep duration and ST were independently associated with overweight/obesity. Additionally, a higher healthy diet score was independently associated with increased odds of being overweight or obese. No significant relationship was found for an unhealthy diet score.

[*] This analysis was repeated using the Treuth[46] MVPA cut-points and IOTF[47] and CDC[48] criteria for overweight/obesity, as a sensitivity analysis (see Appendix 5, Tables 1 and 2 for the results). The same associations were found using the Treuth MVPA cut-points. Only MVPA and sleep duration remained significant using the CDC and IOTF criteria for overweight/obesity, though a lower proportion of participants were classified as overweight or obese using these cut-points (CDC: 20.1% and IOTF:19.3%).

Table 2.1 Descriptive characteristics of the analytic sample (n=374)

		Mean (SD)	
Continuous variables	Total Sample	Boys	Girls
Age (years)	10.9 (0.4)	10.9 (0.4)	10.9 (0.5)
Body height (cm)	145.2 (7.2)	144.5 (6.5)	145.7 (7.6)
Body mass (kg)	39.2 (8.6)	37.9 (7.2)	40.2 (9.4)
BMI z-score	0.4 (1.1)	0.4 (1.0)	0.4 (1.1)
Sedentary time (min/day)	500.8 (55.9)	500.4 (56.7)	501.0 (55.5)
Light-intensity activity (min/day)	288.1 (45.3)	287.3 (43.8)	288.6 (46.5)
MVPA (min/day)	64.4 (22.7)	73.9 (24.9)	57.3 (17.9)
Sleep duration (min/night)	568.3 (43.4)	561.3 (42.4)	573.6 (43.4)
Screen time score	3.0 (1.7)	3.3 (2.0)	2.7 (1.4)
Healthy diet score	0.04 (0.99)	0.06 (0.97)	0.02 (1.01)
Unhealthy diet score	-0.01 (0.99)	0.12 (1.14)	-0.11 (0.84)
Accelerometer wake/wear time (min/day)	853.2 (45.0)	861.7 (44.2)	846.9 (44.7)
Categorical variables*		**N (%)**	
Sex	-	160 (42.8)	214 (57.2)
BMI status (% overweight/obese)	107 (28.6)	41 (25.6)	66 (30.8)
Physical activity (% active)	195 (52.1)	111 (69.4)	84 (39.3)
Screen time (% low ST)	120 (32.1)	44 (27.5)	76 (35.5)
Sleep (% long sleep)	151 (40.4)	52 (32.5)	99 (46.3)
Diet			
Healthy	100 (26.7)	41 (25.6)	59 (27.6)
Mixed	174 (46.5)	75 (46.9)	99 (46.3)
Unhealthy	100 (26.7)	44 (27.5)	56 (26.2)
SES (parental education level)			
Low	105 (28.1)	38 (23.8)	67 (31.3)
Medium	94 (25.1)	41 (25.6)	53 (24.8)
High	175 (46.8)	81 (50.6)	94 (43.9)

*Categories based on children meeting specific criteria: overweight/obese: BMI SD > + 1.0; active: ≥ 60 min MVPA; low ST: ≤ 2.0 hours ST/day; long sleep: ≥ 10.0, 9.75, and 9.5 hours sleep/night for 9, 10 and 11 year olds, respectively. Diet: healthy: > median for healthy diet score and < median for unhealthy diet score; unhealthy: < median for healthy diet score and > median for unhealthy diet score; mixed: all other participants. SES: low: GCSEs/equivalent or less; medium: A Levels/equivalent; high: University degree.

BMI, body mass index; GCSE, General Certificate of Secondary Education; MVPA, moderate-to-vigorous intensity physical activity; SES, socioeconomic status; ST, screen time.

Table 2.2 Odds associated with being overweight/obese in relation to multiple lifestyle behaviours: Odds Ratios* and 95% CIs

	Model 1	**Model 2**
MVPA (min/day)	0.74 (0.56 to 0.97)	0.69 (0.52 to 0.92)
p value	*0.027*	*0.011*
Sleep duration (min/night)	0.66 (0.52 to 0.85)	0.65 (0.51 to 0.83)
p value	*0.001*	*0.001*
Screen time score	1.48 (1.13 to 1.94)	1.50 (1.11 to 2.03)
p value	*0.005*	*0.008*
Healthy diet score	1.24 (0.98 to 1.59)	1.34 (1.04 to 1.73)
p value	0.079	*0.024*
Unhealthy diet score	1.16 (0.92 to 1.46)	1.01 (0.78 to 1.30)
p value	0.219	0.971

Italic font indicates significant results.

*Odds ratios are expressed per standard deviation increase in each variable (MVPA = 23, sleep duration = 43; screen time = 2; healthy diet score = 1; unhealthy diet score = 1).

Model 1: Adjusting for age, sex and SES (parental education level) with schools treated as random effects.

Model 2: All independent variables entered simultaneously in a mutually adjusted model, with covariates. Schools were treated as random effects.

p values are from Type 3 Tests of Fixed Effects.

MVPA, moderate-to-vigorous intensity physical activity; SES, socioeconomic status.

2.5.2 Lifestyle Behaviours and BMI Z-score

PA, ST and sleep duration were significantly associated with BMI z-score in both Models 1 and 2 (Table 2.3). Participants who were sufficiently active had a mean BMI z-score that was 0.42 units lower than those not meeting the MVPA guidelines. Participants meeting the recommended ST and sleep guidelines had a mean BMI z-score approximately 0.30 units lower than those who were not. No significant relationship was found for either dietary variable. Although superseded by interaction effects, PA remained a significant correlate of BMI z-score in all models. Significant interactions were found between PA and sleep; ST and sleep; and PA and diet. These interactions are presented graphically in Figure 2.1.

Table 2.3 Summary of results describing the relationships between BMI z-score and lifestyle behaviours, for different activity, screen time, sleep levels, and dietary groups: β coefficients and 95% CIs

	Model 1	Model 2	Model 3
Physical Activity*			
Active	-0.42 (-0.65 to -0.20)	-0.42 (-0.65 to -0.20)	-1.08 (-1.55 to -0.62)
p value	*<0.001*	*<0.001*	*<0.001*
Screen Time*			
Low ST	-0.30 (-0.53 to -0.07)	-0.29 (-0.52 to -0.06)	-0.56 (-0.85 to -0.27)
p value	*0.012*	*0.014*	0.050
Sleep Duration*			
Long sleep	-0.28 (-0.50 to -0.05)	-0.30 (-0.51 to -0.08)	-0.70 (-1.03 to -0.37)
p value	*0.015*	*0.008*	0.193
Diet*			
Mixed diet	0.15 (-0.11 to 0.42)	0.10 (-0.16 to 0.36)	-0.29 (-0.66 to 0.07)
Healthy diet	0.05 (-0.26 to 0.36)	0.11 (-0.20 to 0.42)	-0.20 (-0.63 to 0.24)
p value	0.489	0.707	0.823
PA x Sleep†			
Active, Long sleep			0.44 (0.01 to 0.87)
p value			*0.044*
ST x Sleep†			
Low ST, Long sleep			0.66 (0.21 to 1.11)
p value			*0.004*
PA x Diet†			
Active, mixed diet			0.74 (0.24 to 1.25)
Active, healthy diet			0.53 (-0.04 to 1.10)
p value			*0.016*

Italic font indicates significant results.

Model 1 is adjusted for age, sex and SES (parental education level), and schools are treated as random effects.

Model 2 is a mutually adjusted model with all covariates and independent variables entered simultaneously, with schools treated as random effects.

Model 3 = Model 2 + significant interactions.

*Reference categories were inactive, high ST, short sleep, and unhealthy diet, respectively.

†Estimates refer to the specified groups. All other possible group combinations act as the referent group.

p values are from Type 3 Tests of Fixed Effects.

BMI, body mass index; PA, physical activity; SES, socioeconomic status; ST, screen time.

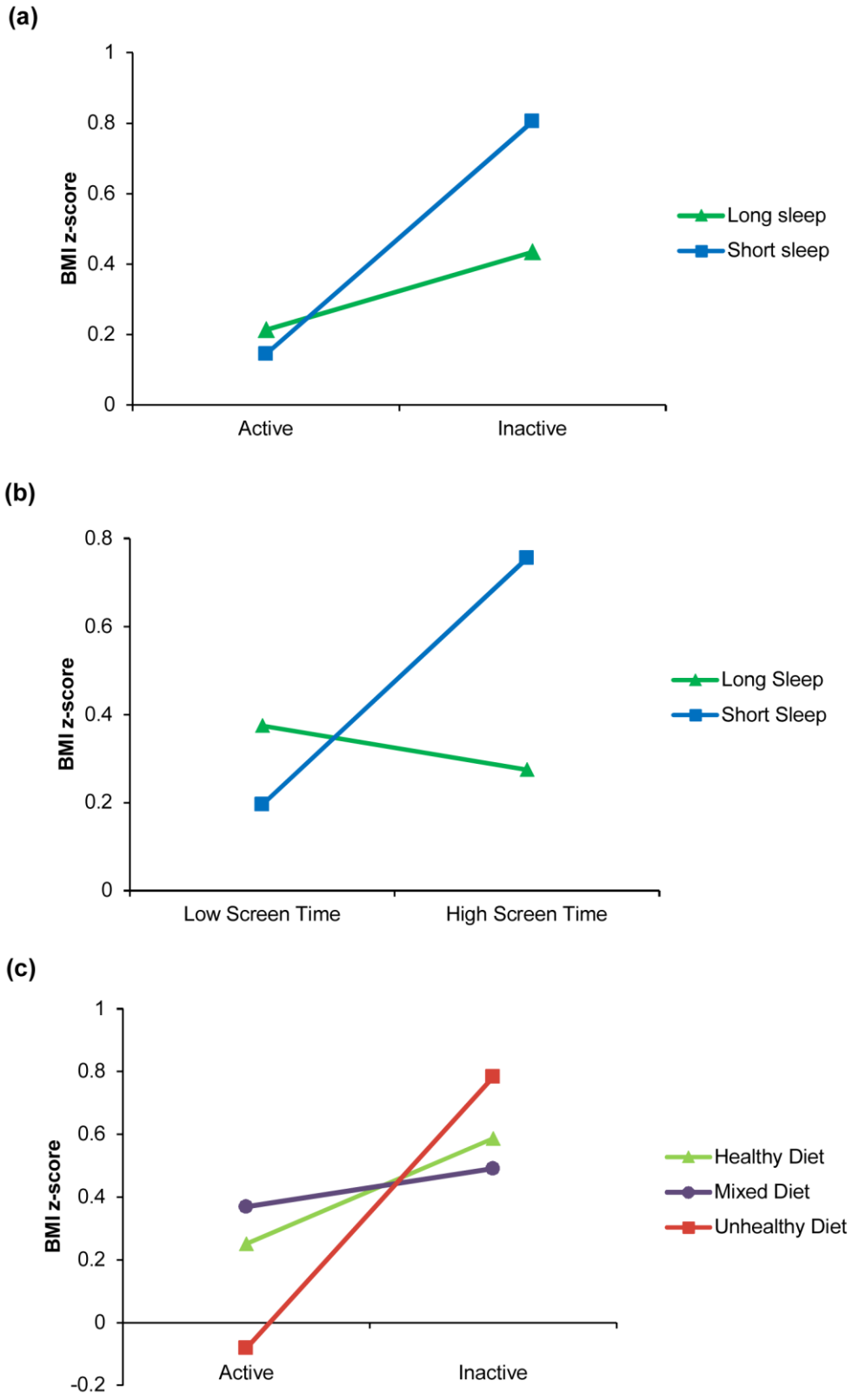

Figure 2.1 Significant interactions among behavioural groups and BMI z-score: (a) PA x sleep interaction (b) ST x sleep interaction (c) PA x diet interaction.

Post-hoc analyses revealed that participants who did not meet either the PA or sleep guidelines had a significantly higher BMI z-score than those who were classified as active, whether they were long (p=0.003, *g*=0.66) or short (p<0.0001, *g*=0.55) sleepers (Figure 2.1a).

As shown in Figure 2.1b, there was a differential effect of sleep duration for those in the high ST group, with long sleepers displaying a significantly lower BMI z-score than short sleepers (p=0.002, *g*=0.48). For children with a short sleep duration, those in the low ST group had a significantly lower BMI z-score than high ST participants (p=0.001, *g*=0.58). Active children with an unhealthy diet had a significantly lower BMI z-score than inactive children for all dietary groups (healthy: p=0.031, *g*=0.47; mixed: p=0.022, *g*=0.46; unhealthy: p=0.001, *g*=0.72; Figure 2.1c), whereas there was no significant difference in BMI z-score between active and inactive children with mixed or healthy diets.

2.6 Discussion

The first aim of this study was to explore the relationships between multiple lifestyle behaviours and overweight/obesity among a sample of UK children. Our results show MVPA, sleep duration, ST and a healthy diet to be independently associated with overweight and obesity. With the exception of a healthy diet score, all relationships were in expected directions, and these findings are similar to those reported across the 12-country ISCOLE sites, in which only obesity status was analysed.[15] A secondary aim was to explore the impact of meeting behavioural guidelines on BMI z-score; meeting guidelines for PA, sleep and ST was significantly associated with a lower BMI z-score and three significant interactions (PA*sleep; ST*sleep; PA*diet) were observed.

Our results for PA are consistent with findings from past UK research, which has shown that higher levels of PA are associated with favourable adiposity levels across different age groups.[19,28,49,50] Not only is PA of at least a moderate intensity and above likely to provide benefit,[49,50] but meeting the MVPA guidelines has also been shown in past work to reduce the likelihood of overweight and obesity.[19,28]

Few studies have explored the role of sleep on adiposity among UK children, but the available evidence from a study on seven year olds,[13] and another on adolescents,[14] is consistent with our findings of an association between short sleep duration and overweight/obesity. This could be a result of metabolic changes

associated with an increase in appetite and subsequently energy intake, which may occur with reduced sleep.[51] Many existing studies have relied on self-reported measures for quantifying sleep[11-14]; thus, our study adds to the existing literature in this area as accelerometers provide a promising indicator of sleep duration, though further research on other samples of UK children is required.

ST, encompassing both TV viewing and computer use, was positively associated with overweight/obesity. Such a finding is consistent with data from adolescents that shows multiple screen-based behaviours (computer use, TV viewing and video games) to be associated with BMI z-score.[14] In a study using data from the HSE,[52] TV viewing was associated with obesity. In contrast, objectively measured sedentary time and other forms of self-reported leisure based sitting were not, though their assessment of 'non-TV sitting' consisted of both screen and non-screen-based pursuits (e.g., homework, drawing, computer use and video games).[52] TV viewing in particular may be a risk factor for adiposity because children are more likely to consume energy-dense foods while watching TV[53,54] and to be exposed to food advertising.[18] However, children are now likely to be exposed to food advertisements via the internet on computers and mobile phone applications,[55] and engaging in screen-based pursuits, particularly before bedtime, may disrupt children's sleep,[56] which could contribute to unfavourable adiposity levels.[14,55] As such, it may be insufficient to target TV viewing alone and future research on other technologies and the possible mechanisms behind their influence with adiposity is warranted.

In addition to movement behaviours, we assessed the role of dietary behaviours on overweight/obesity. Our results were unexpected in that a healthy diet score was associated with an increased risk of overweight/obesity, whereas no such relationship was found for an unhealthy diet score. Similar findings have been reported. For example, less frequent consumption of energy-dense foods was associated with a larger waist circumference in 9-11 year old Swedish children,[16] and among 5-11 year old boys in Scotland, obese participants ate fewer 'snacks' than healthy weight children.[57] One reason for these findings is that overweight children may be eating more healthy food types, or reducing their intake of unhealthy foods in an attempt to lose weight.[16,19] Alternatively, overweight children may be more likely to exaggerate their intake of healthy foods and/or under-report their consumption of unhealthy foods. Dietary intake is a complex behaviour, and considering the potential bias which can arise from self-reported methods, direct

measures of energy intake might prove useful to clarify such findings in future research.

Past work exploring the effects of meeting health behaviour guidelines show some contrasting results to those reported in our work. For example, no significant association was found for ST group and adiposity in a UK study of 9-10 year old children,[28] nor was there a relationship reported for sleep (≥ 8 hours/night) among adolescents in Spain[58] and the US.[59] These differences could in part be explained by methodological differences; the proportion of participants meeting ST guidelines was substantially higher in the UK study than in our sample and different cut-off points were used to classify adequate sleep in the US and Spanish studies. Nevertheless, meeting the PA guidelines was significantly associated with favourable adiposity in all three studies, including our own.

Despite differences in the way that health behaviours have been categorised across studies, it would seem that the more risk factors an individual has (i.e., the more guidelines a child does not meet), the higher the risk of adiposity.[28,58,59] This corresponds with our results, as both interactions for PA x sleep and ST x sleep revealed a similar pattern in that participants who did not meet the guidelines for either behaviour had the highest BMI z-score.

Our results showed that active children classified as having an 'unhealthy' diet overall (i.e., a higher consumption of unhealthy foods and a lower intake of healthy foods) had a significantly lower BMI z-score than their inactive counterparts, and the size of these effects ranged from moderate to large. Ottevaere and colleagues,[60] previously concluded that physically active children do not necessarily consume healthier diets than inactive children, which supports our findings. However, our results should be taken with caution given that diet was self-reported and the direction of causality cannot be inferred. Longitudinal studies would enable researchers to determine the direction of effect and the interplay among such lifestyle behaviours, while qualitative data would provide a deeper understanding of children's and parents' perceptions regarding these two behaviours and their importance in relation to their weight. Nonetheless, lean children who are getting their calorie requirements from unhealthy food types may not be consuming important nutrients necessary for optimal health in accordance with dietary recommendations.[43] As such, parents with lean active children would do well to

ensure that their children eat a healthy diet, especially since consuming a poor diet is known to have other negative health implications.[61]

This study adds to the existing literature on overweight and obesity among UK children by exploring the role of all four modifiable lifestyle behaviours and via the use of accelerometry-derived MVPA and sleep, for which data among UK children are limited. However, accelerometers can only provide a proxy measure of sleep duration and there are other limitations which should be noted. First, causality cannot be inferred due to the cross-sectional nature of the study design. Second, almost 90% of the analytic sample was white British, and data were collected from the South West of the UK. As such, the results may not generalise to other ethnic groups or to children living in other regions of the UK. Third, biological age/maturity was not controlled for in the current study, though the majority of participants were likely to be pre-pubertal. Although every attempt was made to minimise bias, the self-reported measures used in our study are subject to recall and social desirability bias, which may have influenced the results. In particular, the results for diet should be treated with caution due to the difficulties that are imposed when measuring this behaviour.[18] Future research may benefit from using objective measures of dietary intake alongside the objective assessment of other lifestyle behaviours, and given that only TV viewing and computer use were assessed, the role of other screen-based pursuits should also be explored in future work. In addition, it was beyond the scope of the current study to examine the role of lifestyle behaviours across school and weekend days separately.

In conclusion, we have shown that sleep, ST and PA are important behaviours associated with adiposity. Interventions and future research should consider the correlates of overweight and obesity from a multifactorial perspective, taking into account the role of multiple lifestyle behaviours. Further research is needed to confirm our findings for dietary behaviour and sleep duration among a broader sample of UK children in addition to the role of other screen-based pursuits. Our findings confirm the importance of children meeting recommended behavioural guidelines, thus interventions which aim to improve awareness of and compliance with these recommendations are needed.

2.7 References

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Chapter 2 Closing Commentary

The results of this study showed that multiple modifiable lifestyle behaviours were independently associated with indicators of children's body weight (i.e., childhood overweight/obesity and BMI z-score). PA in particular was associated with lower odds of overweight/obesity and shared a significant negative relationship with BMI z-score across all models, independent of other lifestyle behaviours. Additionally, three significant interactions were found, two of which involved PA that emphasised the importance of meeting government recommended levels of MVPA.

This work extends past research and contributes to the field of study as all four lifestyle behaviours were analysed simultaneously utilising objective measures where possible (i.e., accelerometry-derived PA and sleep duration). The significant interactions provide novel information in that children who did not achieve guidelines for more than one behaviour (i.e., for both PA and sleep, or for both ST and sleep) had the highest BMI z-scores. Such findings suggest that compliance with multiple government guidelines for different behaviours should be encouraged. Indeed, Tremblay et al,[96] recently published 24-hour guidelines in Canada, incorporating recommendations for all movement behaviours (i.e., sleep, PA, and sedentary behaviour), in an effort to raise awareness of the importance of complying with all guidelines from day-to-day.

However, the significant interaction for PA*diet was less straight forward because children deemed as 'active' who were considered to have an unhealthy diet had the lowest BMI z-scores on average, while those classified as 'inactive' had the highest BMI z-scores, regardless of their dietary pattern. Such findings would suggest that PA is more important than diet, which contradicts arguments made by other researchers (e.g.,[97]). It is important to emphasise that dietary behaviours are very difficult to measure and the results of our study may have been impacted by social desirability and recall bias inherent within our self-reported assessment of dietary behaviour. Further work, utilising more accurate and objective measures of dietary patterns are needed to corroborate the present findings.

Another potential issue is that the relationships observed in this study were not assessed separately for boys and girls, or across different age and socioeconomic groups. Past research utilising longitudinal data have shown MVPA to be significantly associated with fat mass index and BMI in boys only (with MVPA

displaying protective effects against increases in both markers of body weight).[33,35] In both of these studies, the association was not significant in girls.[33,35] Basterfield et al,[33] suggested that dietary intake may be more important for girls than PA. Whereas, children from lower socioeconomic backgrounds are more likely to be overweight and to eat an unhealthy diet.[5,23] However, age, sex and SES were included as covariates in all analyses and no significant interactions by age or sex were found prior to the main analysis. Further research is needed to gain a better understanding of how interventions should be tailored to specific groups designed to prevent weight gain.

Future work would also benefit from novel analytical methods, such as compositional data analysis. This can address the issue of collinearity associated with accelerometry-derived measures of movement behaviours (i.e., sleep, MVPA, sedentary behaviour etc.), as mentioned previously. This would enable researchers to analyse the impact of such behaviours on indicators of body weight whilst adequately controlling for the effects of one another.

For the remainder of the thesis, PA provides the focus and this behaviour is explored in more detail. Not only were our findings for this particular behaviour more consistent with other research but interventions designed to increase PA levels have had little success in the past.[98] There also appears to be a global physical inactivity crisis,[50] and it was deemed important to gain a better understanding of the extent of the problem among children and young people in England first, by assessing the latest evidence and taking into consideration a number of factors that can influence PA participation in this country.

CHAPTER 3

Results from England's 2016 Report Card on physical activity for children and youth

Chapter 3 Opening Commentary

In focussing the attention of the thesis work on PA, a literature review was conducted to assess the 'state of the nation' with regards to children's PA participation. This appraisal of the extant literature took the form of a Report Card, akin with the Canadian Report Card model.[76] A multifaceted approach was employed and several indicators of PA were assessed including five different activity-related behaviours (viz., overall PA levels, organised sport participation, active play, active transport, and sedentary behaviour) and four levels of influence (schools, family and peers, the neighbourhood and the built environment, and government strategies and investment). Such an approach is used so as to gain a broader understanding of children's PA levels across England, and to examine how we are doing as a country in terms of promoting PA among children and young people. The results in this Chapter represent those from the 2016 Report Card, which provide an update to the first Report Card for England published by Active Healthy Kids England in 2014.[77]

Statement of Authorship

<table>
<tr><td colspan="10">This declaration concerns the article entitled:</td></tr>
<tr><td colspan="10">Results from England’s 2016 Report Card on physical activity for children and youth.</td></tr>
<tr><td colspan="10">Publication status (tick one)</td></tr>
<tr><td>Draft manuscript</td><td></td><td>Submitted</td><td></td><td>In review</td><td></td><td>Accepted</td><td></td><td>Published</td><td>✓</td></tr>
<tr><td>Publication details (reference)</td><td colspan="9">Wilkie H, Standage M, Sherar L, et al. Results From England's 2016 Report Card on physical activity for children and youth. J Phys Act Health. 2016;13(11)(suppl 2):S143-S149. doi:10.1123/jpah.2016-0298.</td></tr>
<tr><td>Candidate’s contribution to the paper (detailed, and also given as a percentage).</td><td colspan="9">Formulation of ideas:
This paper followed an existing model, thus the candidate did not contribute to the overarching ideas and objectives for this paper but the candidate did provide ideas for supplementary material related to the paper. Candidate contribution = 15%

Design of methodology:
The candidate did not conceive the study design pertaining to the Report Card Model that was used, but the candidate considerably contributed to the specific methodology that was employed for this country-specific paper (e.g., the candidate chose specific benchmarks to explore related to existing data). Candidate contribution = 55%

Experimental work:
The candidate conducted the literature search which involved collecting and synthesising all secondary data in preparation for the grade assignment meeting. The candidate chaired the meeting and created all supplementary materials and content aligned with this project. Candidate contribution = 90%

Presentation of data in journal format:
The candidate drafted the entire manuscript in accordance with journal specifications. All other authors provided edits and comments to the paper.
Candidate contribution = 80%</td></tr>
<tr><td>Statement from Candidate</td><td colspan="9">This paper reports on original research I conducted during the period of my Higher Degree by Research candidature.</td></tr>
<tr><td>Signed</td><td colspan="5">  </td><td>Date</td><td colspan="3">25/07/2017</td></tr>
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3.1 Abstract

Background: Regular PA improves physical and mental health, yet children's PA levels were low in England's 2014 Report Card. Within this paper, we update the 2014 Report Card to assess current information for the nine indicators of PA.

Methods: A search for nationally representative data on nine indicators of PA was conducted and the data were assessed by an expert panel. The panel assigned grades (i.e., A, B, C, D, F, or INC (incomplete)) to each indicator based on whether children across England were achieving specific benchmarks. The 2016 Report Card was produced and disseminated.

Results: The following grades were awarded: Overall Physical Activity Levels: D-; Organised Sport Participation: D; Active Play: INC; Active Transportation: C-; Sedentary Behaviours: INC; Family and Peers: INC; School: B+; Community and the Built Environment: B; Government Strategies and Investment: INC.

Conclusions: The grades have not improved since the 2014 Report Card and several gaps in the literature are still present. While children's PA levels remain low alongside competing sedentary choices, further national plans and investment with local actions are urgently needed to promote PA especially via active play, active transport, and family support.

3.2 Introduction

According to government recommendations, children in the UK aged 5-18 years should be engaging in MVPA for at least 60 minutes every day.[1] However, children's PA levels appear to be low. One recent estimate reported that only 9% of boys and 2% of girls achieved sufficient levels of objectively measured PA.[2] Given the health risks[3-5] and the economic costs associated with physical inactivity,[6] it is important to understand the prevalence of PA and sedentary behaviour among children and youth across England, including the extent to which PA is supported by government policy and the built environment.

Active Healthy Kids England was established in 2014 with the aim of providing a 'state of the nation' resource by creating England's first Report Card on Physical Activity for Children and Youth.[7] Several gaps in the literature were identified and PA levels were generally low despite there being evidence of sufficient provision for PA in England.[7]

The purpose of the present paper is to discuss the results of the 2016 Report Card on Physical Activity for Children and Youth. Specifically, we update the 2014 Report Card via the use of newly available data, including published work from a variety of academic and non-academic sources (e.g., from government and non-government organisations).

3.3 Methods

Active Healthy Kids England consists of an expert panel, including several academics from five Universities across England, and a representative involved in research within a leading non-governmental organisation (Youth Sport Trust; YST). The lead author identified key articles and synthesised the evidence from a range of national surveys, published from 2013-2016. The lead author was also responsible for writing the Report Card and additional resources (e.g., website content). All members contributed to the grade assignment process by providing expertise in their relevant field. In addition, the second author was responsible for creating a media and dissemination strategy with assistance from the YST (fifth author).

Nine indicators of PA were assessed, including five activity-related behaviours and four levels of influence: 1) Overall Physical Activity Levels, 2) Organised Sport Participation, 3) Active Play, 4) Active Transportation, 5) Sedentary Behaviours, 6) Family and Peers, 7) School, 8) Community and the Built Environment, and 9) Government Strategies and Investment. These were chosen in order to cover several potential sources of PA and to capture the variety of settings where PA can take place, given the complex and broad nature of children's PA participation. Data used to inform the grades for these indicators were provided from several national surveys including the HBSC study,[8] the HSE,[9] the Millennium Cohort Study (MCS),[10,11] the Taking Part Survey (TPS),[12] the National Travel Survey (NTS),[13] and the YST National PE and Sport Survey.[14] Reports from the government and the Office for Standards in Education, Children's Services and Skills (Ofsted) were also referred to throughout, as were regional datasets and reports from other organisations when data were not available from national surveys.

A meeting was held in April 2016, when members of the expert panel convened to undergo the grade assignment process. The available data were assessed against specific criteria for each indicator, as outlined in Table 3.1. Grades were awarded based on the proportion of children and young people achieving such benchmarks

using the following grade boundaries: A: 81%-100%, B: 61%-80%, C: 41%-60%, D: 21%-40%, F: 0-20%. For example, if 25% of children met the PA guidelines, a D grade would be awarded for the Overall Physical Activity Levels indicator. An incomplete (INC) grade was assigned where insufficient data were available or due to the absence of a suitable benchmark. Given that several sources of data and different figures were available for some indicators, the panel took into account the quality of the data when choosing a grade. The sample size, age range of participants, year of data collection, the reach of the sample (i.e., whether data were collected regionally or across England), and the measures used to collect data were all taken into consideration. Other factors were considered during the group's discussions, including trends in PA behaviours and the presence of any disparities between groups of children (e.g., age, gender, and ethnic differences). When such trends or differences occurred, a + or – grade could be awarded to reflect these. A + or – could also be added to emphasise any data that were of a better quality; reasons were provided in the text to explain such decisions.

3.4 Results

England's 2016 Report Card is the second iteration of a systematic assessment of PA among children and youth. The grades and benchmarks for each indicator are presented in Table 3.1, and the front cover is shown in Figure 3.1. No improvement in any indicator has been made since the 2014 Report Card. For several indicators (Overall Physical Activity Levels, Organised Sports Participation, Active Transportation, and Schools), the grade has declined, whereas for others (Active Play, Sedentary Behaviours, Family and Peers, Community and the Built Environment, Government Strategies and Investment), the grade remains the same.

3.5 Discussion

The expert panel decided to focus the 2016 theme and front cover on informal outdoor PA. The benefits of informal activity, such as active play and active transport, including time spent outdoors in relation to PA are well documented.[15-17] Yet the proportion of children who walk to school has declined since 1995/97,[18] and less than 50% of children use active means to travel to non-school destinations.[11,19] Furthermore, active play typically occurs outside,[20] but it would appear that children spend less time outdoors now than their parents did as they have less 'freedom to roam'.[21,22] Future research is therefore needed on informal outdoor PA, especially

given that time spent indoors may largely consist of engaging in sedentary pursuits.[23]

3.5.1 Overall Physical Activity Levels: D-

A grade of D- was assigned to children's overall PA levels because boys and girls are consistently within the D and F grade boundaries respectively, according to self-reported data from a number of surveys. For example, according to the HBSC, 22% of boys and 15% of girls aged 11, 13 and 15 years are achieving 60 minutes of MVPA per day.[8] Similar figures were reported in the HSE (21% of boys and 16% of girls aged 5-15 years),[9] and the UK Household Longitudinal Study (35.8% of boys and 21.8% of girls aged 10-15 years).[24] Even lower levels were reported among 15 year olds specifically in the What About Youth Survey (18% of boys and 9% of girls).[25] The grade has therefore declined since the 2014 Report Card, in which a grade of C/D was awarded,[7] though this may in part be due to a lack of available data on children younger than 11 years old. There is also a distinct lack of objective data available to grade this indicator, though existing guidelines were developed using self-reported estimates of PA which raises the question of whether current guidelines are suitable given that objective estimates of PA tend to show much lower PA levels. Despite this, these findings emphasise the need for regular monitoring of children's PA levels, using objective measures on a wide age range of children and youth, in order to track changes in PA behaviour over time.[7]

3.5.2 Organised Sport Participation: D

Although data from the Active People and Taking Part Surveys show that > 70% of children and youth were doing sport at least once a week,[12,26] this may include sport inside of school and was therefore not used to inform the grade. On examination of the data for those involved in organised sport outside of school hours the figures are lower. For example, 34.3% of 5-15 year olds reported doing organised sport outside of school; only 27.4% of 11-15s were members of an external sports club and only 19.2% played for a sports team.[12] Yet again, a higher proportion of boys than girls are engaged in organised sport (35% vs. 21%).[27] Aside from sport, 39% of 8-11 year olds participate in organised leisure-time activities once or twice a week and 20% do so every day or almost every day.[28] Given that the majority of data since the last Report Card now resides within the D grade boundary, the grade was reduced from a C- to a D.

3.5.3 Active Play: INC

A lack of available data and appropriate definitional means for measuring this indicator was cited in the 2014 Report Card and an INC grade was assigned.[7] The same issues are still apparent and consequently, an INC grade was awarded again. Despite this, younger children are likely engaging in active play, particularly during school break times.[29] Yet, participation in physically active play declines with age as a function of biological maturity.[30] For example, recent data from the MCS show 80% of 5 year olds engage in active play with a parent at least once or twice a week, whereas 54% of 11 year olds do so.[10] Data are therefore also needed on the type and frequency of unstructured PA performed by adolescents, particularly because it may help to reduce health inequalities.[16]

3.5.4 Active Transportation: C-

Data from the NTS and MCS informed this grade, and similar to the 2014 Report Card, 47%-51% of children actively commute to or from school, though only 2% of these children go by bicycle.[11,13] Approximately 55% of primary schools offered Bikeability cycle training in 2012,[31] though according to a recent evaluation of the scheme, there was no evidence of increased cycling frequency levels among children.[32] Additional measures may be needed, including changes to the built environment (e.g., segregated cycle lanes and traffic free routes), if we are to improve both bicycle safety and cycling levels across England.[33,34]

In terms of active transport to non-school destinations, general bike use is slightly better with 28% of 11 year olds reporting the use of their bike several times a week,[11] and 47% of 2-16 year olds walk for 20 minutes or more, 3 or more times a week.[19] However, boys are more likely to travel on their own by bike (36% vs. 23%) and by foot (54% vs. 44%) than girls, according to the MCS,[11] which likely reflects the higher level of independent mobility typically given to boys.[35] Due to the lack of improvement on this indicator, the consistently low levels of bike use, and the lower proportion of girls making journeys on their own by active means, the panel decided to drop the C grade to a C-. However, it must be noted that some children may use other forms of active travel not considered here (e.g., scooters, roller blades, skate boards, etc.) and some journeys may be made using both passive and active means. An internationally agreed definition and metric of active travel is necessary to facilitate comparisons across countries.

3.5.5 Sedentary Behaviours: INC

An INC grade was assigned to this indicator for a second year, because there are currently no UK guidelines which specify a threshold for sedentary time that can be used as a benchmark.[7] Furthermore, there is a lack of available data on children's engagement in sedentary behaviours with the exception of recreational ST, which shows that 62% of young people reported watching TV and screen-based media for > 2 hours per day.[8] However, past research has focussed heavily on TV viewing alone but children and young people have access to a wide range of screen-based entertainment,[36] thus future research is needed on the effects that this may have on children's health. Data on other non-screen based sedentary behaviours are also required, particularly since children who engage in high ST may be more sedentary in general.[37] In order for a grade to be assigned in future Report Cards, and to advance this area of research, specific evidence-based guidelines for sedentary behaviours are needed in the UK.

3.5.6 Family and Peers: INC

For a second time, an INC grade was awarded to this indicator due to a lack of nationally representative data on family and peer support for PA in England.[7] Data from the YST shows that 53% of parents are engaged in their child's extra-curricular PA and sport at school, though only 8% of these parents are reported to be 'completely engaged' (2015 YST; unpublished custom analysis). However, it is unclear what is meant by 'engaged' in terms of the type of support provided by parents, thus these data were not used to inform a grade. Only one benchmark, which examined the proportion of children doing sport/PA as a family could be assigned a grade. This benchmark was given a D grade because 41% of young people do PA with their family at least once a week.[8]

3.5.7 School: B+

Five benchmarks were assessed, including a new benchmark on the proportion of schools who have a specialist teacher delivering curriculum Physical Education (PE). This new benchmark contributed to the decline in the overall school grade from an A- to a B+ overall.

Data from the PE and Sport Survey[38] were used to inform the A- grade for school PE in the 2014 Report Card.[7] This survey was discontinued from 2010, and PE is no

longer monitored annually across all schools in England.[39] However, data have been collected recently by the YST, which was used to inform the grades for the majority of the school benchmarks. According to this survey, 77% of schools offer at least 2 hours of PE per week at Key Stage 1 (ages 5-7); this rises to 83% and 86% at Key Stages 2 (ages 7-11) and 3 (ages 11-14), respectively, but provision drops to 58% at Key Stage 4 (ages 14-16) (2015 YST; unpublished custom analysis). In addition, > 97% of schools report offering extra-curricular PA and sport, and 85% of secondary and 97% of primary schools report encouraging PA as part of the school day.[14] As such, a B+ was assigned for school PE, and an A grade was awarded to both the availability of additional opportunities and the promotion of daily PA benchmarks. As 57% of schools reported having a specialist PE teacher, with more secondary schools (86%) providing this than primary schools (44%) (2015 YST; unpublished custom analysis), a B- was awarded to the provision of a PE specialist benchmark.

As for the provision of PA facilities at school, data from a report on spending the PE and Sport Premium (£150 million ring-fenced funding provided to all primary schools in England[†]) was used.[41] This report shows that 46% of primary schools have access to outside courts, 64%-78% have access to a multi-purpose school hall, swimming pool and playing field, and 100% have access to a playground.[41] It is a statutory requirement for schools to provide outdoor space for PA, though this does not apply to pupil referral units (an establishment for those who are unable to attend mainstream school),[42] and according to a consultation by Sport England, approximately 3000 primary schools do not have adequate outdoor space for PA and sport.[43] Furthermore, the benchmark specifies that facilities should be in 'good condition', but the only indication of the quality of such facilities is that 47% of schools thought the quality and 45% thought the range of their facilities had improved since the introduction of the PE and Sport Premium.[41] Further, 30% of young people say they would play more sport if their school had better facilities.[27] As such, it is possible that some school facilities may need improvement and little is known about provision across secondary schools. Taking this into account, the grade for this benchmark was reduced from an A to a B+.

[†]This funding will be doubled from April 2018 as part of the new sugar tax.[40]

3.5.8 Community and the Built Environment: B

The grade for this indicator has not changed and remains at a B.[7] Four benchmarks were used to measure this indicator, pertaining to access to and use of outdoor parks and spaces, satisfaction with such spaces and perceptions of safety within the local neighbourhood.

According to data from the MCS, 93.4% of 11 year olds have a playground available to them where they live, and 61.2% of 5 year olds are taken to a playground weekly.[10] Other data show that 70% of children visit the natural environment at least once a week.[44] Consequently, A and B grades were awarded for access to and use of outdoor parks and spaces respectively. In terms of satisfaction with these spaces, a C grade was assigned because 59% of park managers, and 50% of park visitors, feel that their parks are in good condition.[45]

It is promising that 72% of young people agreed that it is safe for children to play outdoors during the day where they live according to the HBSC,[8] and a higher proportion of parents (86.4%),[46] and 11 year olds (89%)[11] report that their home area is safe, according to the MCS. A B+ was awarded to this benchmark to place emphasis on the HBSC data, given that it is more relevant to PA in particular, and the + was included to reflect the higher percentage reported in the MCS. An area for consideration in future Report Cards is the perception of traffic safety and the proportion of children who are allowed to leave the house to play outdoors/actively travel to places unsupervised. This will provide a better indication of neighbourhood safety and whether the spaces near to home are adequately suited to PA behaviours.

3.5.9 Government Strategies and Investment: INC

Numerous government strategies and sources of funding are currently in place, including the government's PA strategy,[47] the PE and Sport Premium,[40] and funding for Change4Life Sports Clubs[48] for example. However, akin to the 2014 Report Card, grading this indicator was difficult due to a lack of independent evaluation of such strategies and policies.[7] Thus, we do not know how successful they are in terms of promoting PA participation among children and youth. However, due to the lack of improvement across all grades in the 2016 Report Card, it would seem unlikely that current policies and strategies are having a significant impact on a large scale.

3.5.10 Strengths and Limitations

The 2016 Report Card has a number of strengths. First, it is the only review of its kind available in England which includes an overall assessment of multiple PA behaviours and varying levels of influence among children and youth. Second, it is a useful resource which can be used by a number of people including public health practitioners, teachers, parents and others that have an influence on children's PA levels. It can also be used to influence future policy directions, serve as a tool for developing future research ideas, and guide research funding priorities.[7] Further, a number of experts in the field were involved in the grade assignment.

Despite these strengths, some limitations should be highlighted. For example, there is a lack of available data to measure some indicators which was also the case for England's 2014 Report Card.[7] Although the best available evidence was used to inform the grades, there is a need for continuous monitoring of children's PA participation using objective measures on a wide age range of participants (e.g., from 2-18 years). In addition, there are still no UK specific guidelines for sedentary behaviour. Such guidelines are needed if we are to grade this indicator in future, and a systematic surveillance tool that captures nationally representative data akin with all benchmarks is needed.

3.5.11 Conclusion

In conclusion, the grades reflect that PA levels are low among children and youth across England. There has been no improvement since the last edition of the Report Card, with many grades having declined, and a lack of available data to measure some indicators. Despite this, there is still sufficient provision of facilities and PA programmes for children and youth, reflected in the B+ and B grades awarded to the school and community indicators. Thus, further work is needed to understand how to promote the use of such facilities and programmes.

Table 3.1 Grades according to PA indicators assessed in England's 2016 Report Card on Physical Activity for Children and Youth

Indicator	Benchmark(s)	Grades
Overall Physical Activity Levels	% of children/youth achieving ≥ 60 minutes of MVPA per day	D-
Organised Sport Participation	% of children/youth participating in organised sport/PA programmes out of school time	D
Active Play	% of children/youth engaging in daily unstructured/unorganised active play	INC
Active Transportation	% of children/youth who use active transport to get to and from places (school, park etc.)	C-
Sedentary Behaviours	% of children/youth meeting sedentary behaviour guidelines	INC
Family & Peers	% of parents who support their children's PA and sport opportunities (e.g., volunteering, paying membership fees, driving, etc.) % of parents who do sport/PA with their children % of children/youth who have friends that support them to be physically active	INC
School	% of schools allocating at least 120 minutes of curriculum PE per week % of schools with specialist PE teachers % of schools that offer additional PA opportunities (excluding PE) % of schools that promote PA as part of the school day % of pupils who have access to PA facilities at school (e.g., sports hall, outdoor playground), in good condition	B+
Community & the Built Environment	% of children/youth with access to outdoor parks and spaces % of children/youth who use outdoor parks and spaces % of children/youth who are satisfied with their local outdoor parks and spaces % of children/parents who perceive their neighbourhood to be safe	B
Government Strategies & Investment	Evidence of allocated funds and PA promotion strategies/initiatives for all children and youth	INC

Note: The grade boundaries for each indicator are: A is 81% to 100%; B is 61% to 80%; C is 41% to 60%, D is 21% to 40%; F is 0% to 20%; INC is Incomplete data.

MVPA, moderate-to-vigorous intensity physical activity; PA, physical activity; PE, physical education.

Figure 3.1 Front Cover of England's 2016 Physical Activity Report Card.
Photos used in this adapted image were purchased from Everett Historical/Shutterstock.com (top photo)[49] and Yorkman/Shutterstock.com (bottom photo).[50]

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Chapter 3 Closing Commentary

Prior to the 2014 Report Card, there had been no overall assessment of children's and young people's PA participation in England which had taken into account several behaviours and different levels of influence. This work therefore provides a significant contribution to the field in several ways. Not only has children's PA participation in England been assessed from a broader and multifaceted perspective, but nationally representative data from several sources have been synthesised and assessed using a unique systematic method (i.e., with a grading system typically seen in school Report Cards) by an expert panel of academics. Several tools were then created including a 'Short Form' Report Card, a website (www.activehealthykidsengland.co.uk) and 'infographics' (please refer to the website to view these), in addition to the supplemental issue of the Journal of Physical Activity and Health.[99] These resources were designed to engage with an array of professionals and stakeholders who work in or whom have a responsibility to promote PA among children and youth. Such tools can therefore be used by several organisations involved in children's health including public health practitioners and those working in policy development as well as researchers.[76] Thus, several suggestions for future research and recommendations were provided throughout and the results from the England Report Card were included in the second 'Global Matrix of Grades', whereby the grades for 38 participating countries were compared.[100]

In summary, the results of the 2016 Report Card were very similar to those reported in 2014 because most of the grades remained the same, although some had declined and it was evident that no improvements were made. As there have only been two years between the two Report Cards, changes in the grades are quite unlikely and for some indicators it was difficult to compare grades because of differences in the data sources used to assess them. Despite this, it was evident that the grades awarded to the school and neighbourhood environment indicators were still higher than those for the actual PA behaviours. It was concluded in the 2014 Report Card that there seems to be plenty of opportunities and sufficient provision for children to engage in PA, but the majority of children are not accumulating enough PA to meet the government recommended amount of 60 minutes MVPA per day.[77] This apparent disconnect between the level of provision and actual PA engagement formed the theme of the 2014 Report Card and a call for more research on how best to increase uptake in sports clubs, free play or active

transport was made.[77] This argument was reiterated in the 2016 paper, but a different theme was chosen as the 'cover story'. Instead, attention was focussed on children's outdoor time and the lack of 'freedom to roam' observed today compared to that of their parents and grandparents.

It is noteworthy that some disagreements were apparent in terms of the grade assignment process among the expert panel of researchers. This was particularly the case for the sedentary behaviour indicator because certain members of the panel wanted to award a grade for recreational screen use according to international ST guidelines that children should not be engaging in more than 2 hours of recreational ST per day.[96,101] Others felt that using these guidelines would only cause confusion since an INC grade was awarded in 2014 due to the fact that these recommendations do not currently exist in England.[77] It was argued that awarding a grade this time round would only weaken the argument for the need to adopt specific sedentary behaviour guidelines in the UK. Furthermore, there has been a lack of evidence pertaining to the displacement hypothesis (i.e., that time in screen-based behaviours displaces PA) in the existing literature.[31]

These issues, the cover story, and other results were kept in mind when planning the objectives of the subsequent empirical Chapters of this thesis. Consequently, the results of the 2016 Report Card will be referred to throughout the remainder of the thesis to show how the grades and cover story were used to inform decisions about subsequent studies.

CHAPTER 4

Correlates of intensity-specific physical activity in 9-11 year old children: a multilevel analysis of UK data from the International Study of Childhood Obesity, Lifestyle and the Environment

Chapter 4 Opening Commentary

Since there appears to be a discrepancy between the amount of provision and actual PA participation among youth across England, the purpose of the following two papers was to gain a more refined understanding of how we might increase children's PA levels. Specifically, we sought to identify correlates associated with different PA outcomes. As there is an existing body of research pertaining to the correlates of PA among children and young people, the primary aim of these next two studies, in the context of the thesis, was to get an idea of important correlates within this particular sample. The results helped to inform future analyses in subsequent chapters, where relationships would be explored in more depth.

However, it was also important to provide new, increasingly applied, information to the existing literature in this area especially because of recent arguments for more contextualised information, seen as correlates may differ according to the time, type or place of PA.[67] Therefore, to increase the specificity and applicability of our findings, we first explored correlates of light-, moderate-, and vigorous-intensity PA as well as those associated with meeting the MVPA guidelines in the following paper.

Statement of Authorship

<table>
<tr><td colspan="10">This declaration concerns the article entitled:</td></tr>
<tr><td colspan="10">Correlates of intensity-specific physical activity in 9-11 year old children: a multilevel analysis of UK data from the International Study of Childhood Obesity, Lifestyle and the Environment.</td></tr>
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<tr><td>Candidate's contribution to the paper (detailed, and also given as a percentage).</td><td colspan="9">Formulation of ideas:
The candidate formulated the ideas for this paper.
Candidate contribution = 95%

Design of methodology:
The candidate did not conceive the study design or methodology employed for the overall ISCOLE study. The candidate selected appropriate variables of interest for the analysis and chose all data analysis techniques.
Candidate contribution = 30%

Experimental work:
The candidate did not contribute to data collection for the ISCOLE study until the closing stages, but the candidate conducted the data analysis.
Candidate contribution = 60%

Presentation of data in journal format:
The candidate was fully responsible for drafting the manuscript in line with guidelines specified by the journal. Remaining authors provided edits to the paper.
Candidate contribution = 85%</td></tr>
<tr><td>Statement from Candidate</td><td colspan="9">This paper reports on original research I conducted during the period of my Higher Degree by Research candidature.</td></tr>
<tr><td>Signed</td><td colspan="5">  </td><td>Date</td><td colspan="3">25/07/2017</td></tr>
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Data access statement: No additional data are available.

4.1 Abstract

Objectives: PA can provide numerous physical and psychological health gains, yet a low proportion of children in England are sufficiently active to accrue benefit. Analysing the correlates of PA from a socio-ecological perspective may help to identify factors that promote versus discourage PA. The purpose of the present study was to: 1) assess the relationships between a wide range of potential correlates and intensity-specific PA; and 2) explore which correlates are associated with meeting government PA guidelines.

Design, setting and participants: Cross-sectional study on 9-11-year-old children from the South West of England (n=425; 183 male).

Outcome measures: Self-reported and objective measures were collected from child participants, parents, and school teachers. After adjusting for covariates (i.e., age, sex, and accelerometer wear time), multilevel modelling techniques were employed to examine the relationships among potential correlates and light-, moderate-, and vigorous-intensity PA, as measured with an ActiGraph GT3X+ accelerometer. Generalised linear mixed modelling was used to analyse the correlates associated with government recommended levels of PA.

Results: Computer-use shared a negative association whereas parent support showed a positive relationship with light-intensity PA. In terms of moderate-intensity PA, computer-use and BMI z-score shared a negative association whereas positive relationships were found for sport participation, active transport, outdoor time after school, and student participation in sport/PA clubs at school. For vigorous-intensity PA, a negative relationship was observed for BMI z-score, and positive associations for self-efficacy, active transport, parent support and the presence of crossing guards on routes to school. Correlates associated with meeting the PA guidelines were BMI z-score (negative), sport participation, active transport, and outdoor time after school (all positive).

Conclusions: The results demonstrate that factors pertaining to the individual, home, and school environment may play an important role when understanding the correlates of differing PA intensities in children.

4.2 Strengths and Limitations of this Study

- Objective measures of PA were employed and data were simultaneously collected from multiple levels of influence.

- This study is limited by its cross-sectional design, and as such the direction of causality cannot be inferred.
- Data were collected from the South West region of the UK and the majority of participants were white British, which may limit the generalisability of our findings.

4.3 Introduction

PA is essential for healthy development in children and youth as it provides a number of physiological and psychological health benefits.[1] Evidence supports the notion that PA can reduce the risk of obesity,[2-4] and the clustering of risk factors for cardiovascular disease.[5,6] Further, PA can improve bone mineral density[7] and enhance emotional health and cognitive functioning among children and youth.[8,9] It is therefore concerning that PA levels in England are critically low, with 79% of boys and 84% of girls (aged 5-15 years) not meeting the UK guidelines[10] of 60 minutes MVPA per day.[11]

Exploring the correlates of PA, and particularly those that are potentially modifiable, is necessary to aid our understanding of how to increase PA levels among children.[12] Yet, this area of research is complex given the number of settings likely to influence children's PA behaviour (e.g., home, school and neighbourhood environments), as illustrated by socio-ecological model approaches (e.g.,[13]). It is therefore important to consider a wide range of correlates from multiple domains, given that focusing on a single domain may give rise to inaccurate conclusions.[12] Despite this, there is a lack of studies simultaneously exploring a range of potential correlates from multiple domains.[14]

There has also been a lack of specificity in terms of how PA is defined. For example, measures of total PA[15] or self-reported leisure time PA[16] have typically been explored. Such approaches can contribute to a loss of important information given that PA consists of different behaviours. Accordingly, Atkin et al[17] have called for a more contextual approach on correlates of particular PA behaviours in order to improve future intervention design. However, PA also requires different levels of exertion and greater health benefits may be gleaned from more intense PA.[7] Yet, light PA contributes the most to overall PA levels, and could appeal more to inactive children looking to become physically active.[18] It is therefore important from both a research and applied perspective (e.g., shaping health-enhancing interventions that are tailored to specific groups), to explore how correlates differ for specific

intensities of PA. Furthermore, examining correlates that are associated with government recommended levels of MVPA will aid our understanding of the typical behaviours and mediators that ought to be targeted in order to increase compliance with these guidelines.

There were two purposes to the present study. First, to analyse the correlates of objectively measured intensity-specific PA, namely light- (LPA), moderate- (MPA) and vigorous-intensity activity (VPA), across several domains of the socio-ecological model in a sample of 9-11 year olds. Second, to explore which correlates are associated with meeting the MVPA guidelines.

4.4 Methods

4.4.1 Study Design

UK-specific data from the ISCOLE study were analysed. A detailed account of the methodology employed within ISCOLE has been provided elsewhere.[19] Children aged 9-11 years were recruited from schools in Bath and North East Somerset and West Wiltshire. Data collection took place during term time from September 2011-January 2013. Informed parental consent and child assent were obtained from all participants. Data collection for the UK site of ISCOLE received ethical approval from the University of Bath 'Research Ethics Approval Committee for Health'.

4.4.2 Outcome Variables

Each participant wore an ActiGraph GT3X+ Accelerometer (ActiGraph LLC, Pensacola, FL, USA) attached to an elastic belt, on the right hip, for up to 7 full days.[19] A 24-hour monitoring protocol was implemented in order to improve compliance; thus, participants were encouraged to wear the monitor at all times except during water-based activities.[19,20] A detailed explanation of how the data were treated has been provided elsewhere.[20] Briefly, time spent sleeping was identified using a published fully automated algorithm,[21] and a subsequent algorithm was run to identify periods of non-wear (20 consecutive minutes of zero activity counts[22]).[20] All remaining minutes were therefore identified as waking wear time.[20] Data were considered acceptable if participants wore the device for at least 4 days including one weekend day and had ≥ 10 hours of waking wear time per day.[20] Accelerometer cut-points developed by Evenson et al,[23] were used to quantify LPA (26–573 counts/15s), MPA (574–1002 counts/15s), and VPA (≥1003 counts/15s) as these are recommended over other cut-points.[24] For the second objective,

participants were classified as 'meeting the MVPA guidelines' if their mean amount of time spent in MVPA (≥574 counts/15s)[23] per day was ≥ 60 minutes, in accordance with the UK PA recommendations.[11] Children not achieving this were classified as 'not meeting the MVPA guidelines'.

4.4.3 Potential Correlates

Correlates for this study were chosen *a priori* based on previous research (e.g.,[15,25-27]). These variables covered several domains of the socio-ecological model,[13] and were grouped accordingly: demographic/biological; psychological; behavioural; home and school environmental factors.

4.4.3.1. Demographic/Biological

During a visit to the school, participants' stature was measured using a Seca 213 portable stadiometer (Seca Corporation, Hamburg, Germany) and their body mass was measured using a portable Tanita SC-240 Body Composition Analyser (TANITA Corporation, Tokyo, Japan).[19] Each measurement was repeated twice, or three times if the first two measurements were > 0.5 cm or 0.5 kg apart, and the average of the two closest measurements was used for analysis.[19] BMI was calculated (body mass (kg)/height $(m)^2$) and their BMI z-score was derived using WHO growth reference data.[28]

Information was also collected from the participant's main caregiver pertaining to their sex and date of birth. Decimal age at the time of data collection was then calculated.

4.4.3.2. Psychological

A Diet and Lifestyle Questionnaire was administered to all participants. The children were asked how much they agreed/disagreed with a number of statements (e.g., "I can be physically active during my free time on most days"), to measure their self-efficacy for PA, using a validated questionnaire.[29] There were eight items in total and responses were coded on a scale of 0 (disagree a lot) to 4 (agree a lot). The mean of all items was computed to create a composite self-efficacy score.

4.4.3.3. Behavioural

Participants were also asked about how much time they spent in specific behaviours. First, they were asked how many hours they had spent watching TV on

both school and weekend days in the past week, choosing from 7 options coded as: I did not watch any hours of TV (0); <1 hour (0.5); 1 hour (1); 2 hours (2); 3 hours (3); 4 hours (4); 5 or more hours (5). Using this information, a weighted mean score of TV viewing was calculated using the formula: (school day TV*5 + weekend TV*2)/7. Computer use across the week was also calculated using this formula, as participants were asked about how often they played video/computer games or used a computer for anything but school work in the last week. These items were taken from the US Youth Risk Behavior Surveillance System,[30] which possess sufficient reliability and validity.[31] Second, participants were asked if they had participated in sports teams during the past year with a simple 'yes' or 'no' question. Third, questions regarding participants' active transport to school were adapted from the Canadian HBSC study.[32] The children were asked how they travelled to school in the last week for the main part of their journey. The following were considered active transport modes: walking, bicycle, roller-blade, skateboard and scooter. Passive forms of transport included: bus, train, tram, underground, boat, car, motorcycle or moped.

4.4.3.4. Home Environment

Parents/guardians were asked to provide information on their SES, ascertained from the combined annual income for their household (before taxes) and their highest level of education. Due to a large amount of missing data on family income, parental education was used as an indicator of SES. Data were collapsed into the following three categories: low (GCSEs/equivalent, some secondary school or less); middle (A levels/equivalent); high (Bachelor's degree or Graduate/professional degree).

Items from the Neighborhood Impact on Kids Survey[33] were used to assess parent support. The main caregiver was asked how often in a typical week (never, 1-2 days, 3-4 days, 5-6 days, or every day) they (1.) encourage their child to do sport/PA, (2.) provide transport to sports/PA clubs, (3.) watch their child participate in such activity and (4.) how often they do sport or PA with their child. Responses were coded on a scale of 0 (never) to 4 (every day), and the mean score was computed. Additionally, parents were asked if their child owned a mobile phone or 2-way radio/walkie talkie with a simple 'yes' or 'no' question.

Data on outdoor time after school were collected from the children. Participants were asked how long they spent outside after school before bedtime, in the last

week (<1 hour, 1 hour, 2 hours, 3 hours, 4 hours, and ≥ 5 hours). Responses were coded on a scale of 0-5 and this was treated as a continuous variable.

4.4.3.5. School Environment

School administrators also completed a questionnaire, which included items that were adapted from the Healthy School Planner,[34] employed in the Canadian School Health Action, Planning and Evaluation System.[35] First, they were asked 'What percentage of pupils participate in school sports or PA clubs (including dance) offered by your school: Not available, < 10%, 10-24%, 25-49%, or ≥ 50%'. All participating schools had these clubs on offer and only one had < 10% of pupils doing such activities. Responses for both < 10% and 10-24% were therefore collapsed into one category (≤ 24%). Second, school administrators were asked whether there are safe walk-to-school routes present via the following yes/no/don't know question: 'Does your school provide crossing guards at intersections to encourage safe walk-to-school routes?'; all schools responded either yes or no. Third, administrators were asked: 'How much of a problem is heavy traffic in the neighbourhood where this school is located: a major problem, moderate problem, minor problem, not a problem, don't know'. No schools selected 'don't know', thus results were collapsed into two categories: problematic (major or moderate) and not problematic (minor and not a problem).

4.4.4 Statistical Analysis

All analyses were conducted in SAS Studio 3.5 (SAS Institute Inc., Cary, NC, USA, 2012-2016). Participants were included in the analysis if they had complete data for all potential correlates, including valid accelerometry data. Descriptive statistics were computed and compared between included and excluded participants. To address the first objective, simple multilevel linear regression was conducted first to analyse associations between each independent variable and the PA outcomes (LPA, MPA and VPA) using the MIXED procedure. Age and sex were included as covariates in all models, given their consistent relationships with PA reported in the literature.[15] The mean waking wear time per day was computed and also included as a covariate, and schools were treated as random effects in all models. Variables associated with PA at $p<0.10$ were included in multiple multilevel linear regression models. This less stringent criteria was used in order to avoid important variables from being excluded.[36] Variables were entered in the following order: biological and psychological, followed by behavioural, then home, and finally school-level

correlates. Variables with a p value > 0.10 were removed before the next set of variables were entered, and if more than one was non-significant, the variable with the highest p value was removed first. This process was continued until only significant variables ($p<0.05$) were left; these were considered to be correlates of PA.[37] Generalised linear mixed modelling using the GLIMMIX procedure was employed to examine the second objective pertaining to which variables were associated with meeting the MVPA guidelines. In Model 1, simple associations between each potential correlate and the dependent variable (i.e., meeting the MVPA guidelines vs. not meeting the MVPA guidelines) were conducted, adjusting for covariates only and with schools treated as random effects. In Model 2, all significant variables ($p<0.05$) from Model 1 were included, and those that remained significant in Model 2 were considered to be correlates associated with meeting the MVPA guidelines. Checks for normality, multicollinearity, and linearity were performed, and unless stated, no problems regarding these assumptions were identified.

4.5 Results

From 26 participating schools, 541 students consented to take part in the study. After withdrawals (n=8), and excluding those without complete data, the analytic sample for this study was 425 participants. Excluded participants were more likely to be male, have a higher mean BMI z-score, and have lower PA on average. The intra-class correlation revealed that approximately 23%, 18% and 6% of the variation for LPA, MPA and VPA respectively was explained by school-level factors, whereas 7% of the variation in being classified as meeting/not meeting the MVPA guidelines was explained at the school level. The remaining proportion of the variability in each outcome was therefore explained by individual or unknown factors. Descriptive characteristics of the analytic sample for child- and school-level variables are provided in Tables 4.1 and 4.2, respectively.

Table 4.1 Descriptive characteristics of the analytic sample for all child-level variables (n=425)

Variable	Mean (SD) or N (%)
Demographic/Biological	
Age (years)	10.9 (0.4)
Sex (% male)	183 (43.1)
BMI z-score*	0.4 (1.1)
Psychological	
Self-efficacy score	2.5 (0.8)
Behavioural	
TV viewing score	1.8 (1.0)
Computer use score	1.2 (1.1)
Sport participation (% Yes)	292 (68.7)
Transport mode to school (% Active)	276 (64.9)
Home environment	
SES (Highest parental education level)	
University degree	199 (46.8)
A Levels or equivalent	105 (24.7)
GCSEs or less	121 (28.5)
Parent support score	1.6 (0.8)
Ownership of a mobile phone (% Yes)	243 (57.2)
Outdoor time after school (hours/day)	1.7 (1.3)
Outcome Variables	
LPA (min/day)	286.3 (45.2)
MPA (min/day)	43.3 (13.0)
VPA (min/day)	20.9 (11.5)
% Meeting the MVPA guidelines†	224 (52.7)
Mean accelerometer waking wear time (min/day)	845.7 (49.7)

*BMI z-score was derived from WHO growth reference data.[28]

†% of children with a mean of at least 60 minutes of MVPA per day.[11]

BMI, body mass index; GCSE, General Certificate of Secondary Education; LPA, light-intensity physical activity; MPA, moderate-intensity physical activity; SES, socioeconomic status; TV, television; VPA, vigorous-intensity physical activity.

Table 4.2 Descriptive characteristics of the school-level variables (n=26)

Variable	N (%)
Student participation in school sport/physical activity clubs	
≤ 24%	8 (30.8)
25-49%	10 (38.5)
≥ 50%	8 (30.8)
Presence of crossing guards on routes to school (% Yes)	15 (57.7)
Heavy traffic in school neighbourhood (% Problematic)	17 (65.4)

4.5.1 Correlates of LPA, MPA and VPA

Table 4.3 shows the simple associations between potential correlates and each outcome variable, adjusting for covariates. Computer use, ownership of a mobile phone (both negative), sport participation, parent support, and outdoor time after school (all positive) were associated with LPA ($p<0.10$), and subsequently included in multiple regression analyses. As for MPA and VPA, positive relationships were found for self-efficacy, sport, active transport, parent support, outdoor time after school, and for presence of school crossing guards, whereas a negative association was found for BMI z-score with both outcomes. In addition, computer use (negative) and student participation in school sport/PA clubs (positive) were related to MPA. No significant associations were found for TV viewing, SES, or heavy traffic in the school neighbourhood for either outcome. Due to a slight positive skew in VPA (skewness = 1.2), a square root transformation was applied, but the same patterns were observed. As such, results using the original scale are presented for ease of interpretation.

Results from the final models are displayed in Table 4.4. Only computer use (negative) and parent support (positive) were associated with LPA. Computer use was also negatively associated with MPA. The other behavioural variables, sport participation and active transport, displayed a significant positive relationship with MPA, in addition to outdoor time after school and student participation in sport/PA clubs. Children who attended schools with 25-49% of pupils doing sport/PA clubs did 6.0 more minutes of MPA per day than those at schools with fewer pupils participating in such activities; no significant difference was found between the highest (≥ 50%) and lowest (≤ 24%) categories. In contrast, BMI z-score was negatively associated with MPA, and the same relationship was observed for VPA. Whereas, self-efficacy, parent support, and the presence of school crossing guards were positively associated with VPA. Active transport was also included in the model for VPA given that it verged on significance ($p=0.050$), and because this variable was significantly associated with the transformed data ($p=0.029$) in the same direction (positive). No differences in the results were found whether this variable was included or excluded from the model, and all other results for the transformed data followed the same patterns (i.e., providing confidence in the raw metric of the data).

Table 4.3 Simple associations between potential correlates and intensity-specific physical activity (LPA, MPA, VPA), adjusting for age, sex and mean accelerometer wear time: β-coefficients and 95% CIs (n=425)

	LPA		MPA		VPA	
	β (95% CI)	**p value**	**β (95% CI)**	**p value**	**β (95% CI)**	**p value**
BMI z-score	0.52 (-2.88 to 3.92)	0.764	-1.52 (-2.51 to -0.53)	**0.003**	-1.99 (-2.89 to -1.08)	**<.0001**
Self-efficacy	1.63 (-3.25 to 6.50)	0.513	2.91 (1.51 to 4.31)	**<.0001**	2.85 (1.57 to 4.14)	**<.0001**
TV viewing	1.93 (-1.61 to 5.46)	0.284	-0.28 (-1.32 to 0.75)	0.590	-0.09 (-1.05 to 0.87)	0.854
Computer use	-4.83 (-8.58 to -1.09)	**0.012**	-1.48 (-2.58 to -0.38)	**0.008**	-0.54 (-1.55 to 0.48)	0.301
Sport participation (Ref = No sport)	7.51 (-0.45 to 15.47)	**0.064**	3.47 (1.15 to 5.79)	**0.004**	2.64 (0.48 to 4.80)	**0.017**
Active transport (Ref = Passive transport)	-6.05 (-14.01 to 1.91)	0.136	5.62 (3.34 to 7.90)	**<.0001**	2.42 (0.30 to 4.55)	**0.025**
SES (Parental education level)						
University degree	Ref	0.422	Ref	0.635	Ref	0.343
A Levels	6.15 (-3.05 to 15.34)	0.189	-0.39 (-3.09 to 2.32)	0.779	-0.48 (-2.97 to 2.00)	0.703
GCSEs or less	2.71 (-6.58 to 11.99)	0.567	1.00 (-1.72 to 3.73)	0.470	1.45 (-1.02 to 3.92)	0.249
Parent support	6.24 (1.67 to 10.81)	**0.008**	1.94 (0.60 to 3.28)	**0.005**	1.80 (0.55 to 3.04)	**0.005**
Ownership of a mobile phone (Ref = No mobile)	-7.95 (-16.12 to 0.21)	**0.056**	-1.65 (-4.05 to 0.76)	0.179	-1.80 (-3.98 to 0.39)	0.107
Outdoor time after school	2.66 (-0.11 to 5.42)	**0.060**	1.53 (0.73 to 2.33)	**0.000**	0.79 (0.05 to 1.53)	**0.038**
Student participation in school sport/PA clubs						
≤ 24%	Ref	0.740	Ref	**0.008**	Ref	0.224
25%-49%	5.64 (-18.12 to 29.39)	0.641	6.18 (0.63 to 11.73)	**0.029**	1.88 (-1.85 to 5.62)	0.322
≥ 50%	-3.69 (-29.18 to 21.81)	0.776	-2.36 (-8.38 to 3.66)	0.441	-1.50 (-5.66 to 2.66)	0.479
Presence of school crossing guards (Ref = None)	-8.23 (-27.80 to 11.33)	0.409	5.60 (0.47 to 10.72)	**0.032**	3.63 (0.52 to 6.75)	**0.023**
Heavy traffic around school (Ref =Not a problem)	-4.76 (-25.20 to 15.68)	0.647	-0.96 (-6.65 to 4.73)	0.740	-1.99 (-5.26 to 1.27)	0.231

Schools were treated as random effects in all models.

BMI, body mass index; GCSE, General Certificate of Secondary Education; LPA, light-intensity physical activity; MPA, moderate-intensity physical activity; PA, physical activity; Ref, reference category; SES, socioeconomic status; TV, television viewing; VPA, vigorous-intensity physical activity.

Bold font indicates significant results (p<0.10).

Table 4.4 Final models showing correlates of LPA, MPA and VPA: β-coefficients and 95% CIs

		β (95% CI)	p value
LPA	Computer use	-4.31 (-8.06 to -0.57)	0.024
	Parent support	5.65 (1.07 to 10.22)	0.016
MPA	BMI z-score	-1.35 (-2.28 to -0.42)	0.005
	Computer use	-1.22 (-2.28 to -0.15)	0.025
	Sport participation (Ref = No sport)	2.97 (0.73 to 5.21)	0.009
	Active transport (Ref = Passive transport)	5.63 (3.44 to 7.81)	<.0001
	Outdoor time after school	1.55 (0.79 to 2.30)	<.0001
	Student participation in school sport/PA clubs		
	≤ 24%	Ref	0.006
	25%-49%	5.97 (0.53 to 11.41)	0.032
	≥ 50%	-2.75 (-8.65 to 3.16)	0.361
VPA	BMI z-score	-1.60 (-2.51 to -0.69)	0.001
	Self-efficacy	1.89 (0.56 to 3.22)	0.006
	Active Transport (Ref = Passive Transport)	2.05 (0.00 to 4.10)	0.050
	Parent support	1.36 (0.12 to 2.60)	0.032
	Presence of school crossing guards (Ref = None)	3.21 (0.34 to 6.07)	0.028

All models were adjusted for age, sex and mean accelerometer wear time, with schools treated as random effects.

BMI, body mass index; LPA, light-intensity physical activity; MPA, moderate-intensity physical activity; PA, physical activity; Ref, reference category; VPA, vigorous-intensity physical activity

4.5.2 Correlates Associated with Meeting the MVPA Guidelines

As shown in Table 4.5, BMI z-score (negative), and self-efficacy, sport participation, active transport, parent support and outdoor time after school (all positive) displayed a significant relationship in Model 1. All these variables were included in Model 2. An increase in BMI z-score was associated with reduced odds of being classified as active whereas more time spent outdoors after school was associated with increased odds of meeting the MVPA guidelines. Children who engaged in sport participation and active transport were 1.73 and 2.38 times more likely to be sufficiently active, respectively, than those who did not. The relationships for self-efficacy and parent support were no longer significant in Model 2.

Table 4.5 Correlates associated with meeting the MVPA guidelines (≥ 60 minutes of MVPA per day): Odds Ratios and 95% CIs

	Model 1	**Model 2**
	OR (95% CI)	OR (95% CI)
BMI z-score	0.71 (0.58 to 0.87)*	0.71 (0.57 to 0.88)*
Self-efficacy	1.49 (1.12 to 1.98)*	1.06 (0.77 to 1.46)
TV viewing	0.90 (0.74 to 1.11)	
Computer use	0.86 (0.69 to 1.07)	
Sport participation (Ref = No sport)	1.75 (1.10 to 2.79)*	1.73 (1.04 to 2.88)*
Active transport (Ref = Passive transport)	2.22 (1.40 to 3.52)*	2.38 (1.46 to 3.87)*
SES (Parental education level)		
University degree	Ref	
A Levels/Equivalent	1.12 (0.66 to 1.90)	
GCSEs or Less	1.49 (0.88 to 2.54)	
Parent support	1.40 (1.06 to 1.83)*	1.22 (0.90 to 1.64)
Ownership of a mobile phone (Ref = No mobile)	0.89 (0.56 to 1.41)	
Outdoor time after school	1.32 (1.12 to 1.56)*	1.32 (1.11 to 1.58)*
Student participation in school sport/PA clubs		
≤ 24%	Ref	
25%-49%	1.21 (0.55 to 2.67)	
≥ 50%	0.60 (0.25 to 1.46)	
Presence of school crossing guards (Ref = None)	1.90 (0.95 to 3.79)	
Heavy traffic around school (Ref =Not a problem)	0.71 (0.35 to 1.41)	

Odds ratios for continuous variables are expressed as a 1 unit increase from the mean.

Model 1 = Adjusted for age, sex, and mean accelerometer wear time, with schools treated as random effects.

Model 2 = Mutually adjusted model with significant correlates from Model 1 entered simultaneously, adjusting for covariates (age, sex, mean accelerometer wear time) and schools treated as random effects.

BMI, body mass index; GCSE, General Certificate of Secondary Education; MVPA, moderate-to-vigorous intensity physical activity; PA, physical activity; Ref, reference category; SES, socioeconomic status; TV, television.

*p<0.05

4.6 Discussion

The aims of this paper were i.) to explore correlates of intensity-specific PA; and ii.) to analyse correlates associated with meeting the MVPA guidelines. Potential correlates from multiple domains of the socio-ecological model were chosen to provide a broader indication of the correlates associated with different intensities of children's PA.

Computer use was negatively associated with lighter-intensity PA (LPA and MPA) in the current study, while TV viewing was not significantly associated with any of the PA outcomes. According to a recent meta-analysis, evidence that sedentary behaviour displaces PA is weak, and the two may instead co-exist.[38] Specific sedentary behaviours were assessed and a significant negative, albeit small, relationship was found between TV viewing and PA, whereas computer use was not

significantly associated with PA.[38] These findings contrast with our results but the authors pooled together all PA outcomes and they did not distinguish between specific PA intensities,[38] which could explain these differences. In another meta-analysis, TV viewing displayed a significant negative relationship with VPA but this association disappeared when computer use was added to form a composite measure of ST.[39] Taken together, it is possible that there may be contrasting effects for different screen-based behaviours depending on how they are defined and according to the type or intensity of PA in question. Further research is needed to gain a better understanding of these differences and to explore the role of other sedentary pursuits in relation to children's PA, given the increased use of new screen-based leisure technologies.[40]

The activity-related behaviours of sport participation and active transport were both positively associated with PA of at least a moderate intensity. Evidence from other research has shown that both sport participation and active transport can make a significant contribution to children's MVPA,[41-46] but for active transport, the further the distance travelled, the greater the contribution.[44,47] A significant positive relationship was also observed for time spent outdoors after school with MPA and compliance with the MVPA guidelines. This finding concurs with a review,[48] and a UK study[49]; the latter reporting that children who spent longer outdoors were more active than those residing indoors, as measured by GPS.[49] There is arguably more space outside and subsequently a greater opportunity for higher intensity activity, whereas more opportunities to engage in sedentary based pursuits are available inside the home.[48] Encouraging more time outdoors, or promoting participation in at least one specific PA behaviour (e.g., active transport or sport participation) could provide benefits, given that each behaviour was independently associated with meeting the MVPA guidelines.

BMI z-score was negatively associated with MPA, VPA, and meeting the MVPA guidelines. These findings are consistent with the negative relationship between MVPA and markers of adiposity generally reported.[2,3,25,50-52] However, a review of reviews reported an inconsistent relationship between BMI and PA among children.[15] While some studies report no association between total PA and BMI,[51,53] others have found a negative relationship.[3,52] Previous research suggests this inconsistency could partly be due to a different association between BMI and LPA than with total PA (i.e., positive for LPA vs. negative for total PA).[52] Abbott and Davies[54] suggested that there may be an intensity threshold required for a

significant reduction in body composition to take place. These findings provide support for the benefits of higher intensity PA in relation to adiposity, but strategies aimed at increasing such PA among those with an unhealthy body weight are needed.

Self-efficacy was also associated with MPA, VPA, and meeting the MVPA guidelines in the simple models, but in the multiple regression analysis it remained significantly positively associated with VPA only. Such a finding concurs with past work showing a positive relationship between self-efficacy and VPA and no relationship with MPA.[55,56] However, both studies are dated with more recent research reporting positive relationships between self-efficacy and MVPA.[57-59] It is unclear as to why self-efficacy was not associated with MPA or the MVPA guidelines in our study, yet it is pertinent to refer to Bandura's self-efficacy theory,[60] which hypothesises that an individual's perception of their ability to undertake an activity will govern their persistence during times of difficulty. As VPA requires more physical exertion than MPA, it may be that a higher level of perceived self-efficacy is warranted to execute activities of this kind. Given the potentially superior benefits associated with VPA,[7] intervention efforts which aim to enhance perceptions of self-efficacy, particularly for strenuous activity, might therefore be important.

Parent support was positively associated with all outcomes in the simple models, but in the mutually adjusted models it only remained a significant correlate of both LPA and VPA. Reasons for this are unclear, yet parent support was identified as a consistent correlate of PA in a review of reviews,[26] and it may mediate positive associations between parent's and children's activity levels.[61] However, it is worth noting that parent support has previously been associated with organised PA, not free-time PA,[62] and the items used in our study may have been more relevant to organised activities, such as sport. Nevertheless, encouraging parents to support their children's PA in general should be a key focus of future intervention efforts.

School environmental variables were also analysed. First, a positive relationship between the presence of crossing-guards on routes to school and VPA was found. Those who went to schools where this was in place did approximately 3 more minutes of VPA than those attending schools without such a policy. In a study of school-level correlates among 9-10 year olds from Norfolk, having a school crossing guard was positively associated with MPA.[27] In their study, 40.7% of schools had this in place,[27] whereas 57.7% of schools did so in our work. As such, there are still a number of schools which do not provide crossing guards, and we agree with the

authors that such a strategy may be worth implementing and evaluating at schools where this is currently not in place.[27]

Children who went to schools with 25%-49% of pupils participating in PA/sport clubs did approximately 6 more minutes of MPA than those at schools with fewer students engaging in such activity. Schools with higher levels of sport participation might have a positive ethos towards PA, which could explain their higher activity levels because the more children taking part, the more likely that their friends will join in as well. Indeed, past work has shown children tend to have similar PA levels to that of their school peer groups.[63] However, in both these cases there could be other environmental factors such as school size, provision of facilities and available space that have interacting effects and further research is required to delve into the specific relationships at play.

The use of objectively measured PA is a major strength of this study, providing a more robust assessment than self-reported measures. However, accelerometers do not capture cycling adequately nor water-based PA such as swimming. Although intensity-specific PA was analysed, which provides new information beyond total PA alone, we realise that each outcome was based on mean daily values. This does not provide specific contextual information on the PA type or time when PA is undertaken. It is important to note that some of the self-reported measures employed in this study have not been validated (e.g., the item measuring time spent outdoors after school was developed by the ISCOLE team[19]). In addition, the direction of causality cannot be inferred due to the cross-sectional study design and the majority of participants were white British, so it was not possible to assess the role of ethnicity and our findings may not generalise to other regions of the UK.

In conclusion, a number of correlates from multiple domains were associated with PA and it would appear that some may only apply to specific intensities (e.g., computer use and self-efficacy), though more research is required to confirm this. According to the results of our study, interventions which promote physically active behaviours such as sport, active transport and outdoor time after school may help to promote compliance with PA guidelines, and particular attention for children with an unhealthy body weight is needed. Intervention efforts that aim to encourage parents to support their children's PA, and those which target the school PA environment might also be effective.

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Chapter 4 Closing Commentary

Correlates from multiple levels of influence (i.e., individual, home, neighbourhood, and school environments) were assessed in order to examine PA from a multifactorial perspective, concurrent with the theme of the thesis. The results provided a broad indication of the types of behaviours and environments that may be important among UK children as several correlates from a variety of domains were associated with PA of differing intensities.

Several behaviours were assessed akin with the Report Card (i.e., sedentary behaviour, active transport, and sport participation) in order to see whether some were more important correlates than others in terms of increasing or decreasing specific intensities of PA. This provided insight into which behaviours might require further research in Chapter 6, where the aim was to explore a specific type of PA. It was evident from the results that time spent in physically active behaviours (sport and active travel) were associated with meeting the MVPA guidelines. Outdoor time after school was also identified as a correlate of meeting the MVPA guidelines, and it was decided that this variable should be viewed as a behaviour throughout the remainder of the thesis. It was originally viewed as an environmental correlate akin with other research.[65] However, even though it is likely influenced by environmental factors pertaining to the home and neighbourhood (e.g., parental safety concerns and local facilities),[65] it is still a behaviour that is performed by an individual and our results support previous research, that time outdoors can be used as a proxy measure of PA.[102]

A limitation of this type of research is that there is an element of chance with regards to the correlates that are chosen to be analysed, given a huge variety of possible influential factors as well as the model building process that is employed. However, it is not possible to include all potential correlates and it is important to achieve a parsimonious model. Thus, correlates included in this study were chosen carefully using the findings from past empirical research and to reflect a broad range of domains to gain a more comprehensive understanding of which settings might be most influential. For example, potential correlates that had inconsistent or unclear relationships with PA according to previous research were included (such as ST, SES and self-efficacy).[64,103] Some were chosen despite consistent relationships with PA in past work (e.g., active transport and outdoor time) to assess whether such relationships were consistent in this sample of children. Further, different features from each domain were included in order to avoid multicollinearity (e.g., different

factors pertaining to the school environment were chosen to reflect both sport and active transport policies). This same premise was applied in Chapter 5.

CHAPTER 5

Correlates of children's physical activity outside of school hours: results from ISCOLE-UK.

Chapter 5 Opening Commentary

The next development of the thesis, and objective of the following paper, was to look at PA performed during specific times, given that correlates may also differ according to the time and essentially the context in question.[67] We chose to explore PA performed outside of school hours because this is when children have free time and more choice over their behaviour. It is also when ST is likely to be more prominent and may compete for time in PA outside of school.[65] Yet, less research has been conducted on correlates of time-specific PA, thus PA performed before school, after school, and on weekend days was examined.

Again, we explored potential correlates from multiple levels of influence. This provided a broader indication of the types of behaviours and environments that may be important during particular times outside of school hours. Past research and the need for parsimonious models were considered when choosing variables for analysis.

Time spent in MVPA was explored to enable comparisons with past research and because few correlates were associated with LPA in Chapter 4. Correlates that were only associated with LPA or VPA in the former study were not included (i.e., self-efficacy, parent support, and presence of school crossing guards) and other changes were made in order to expand the breadth of potential correlates being explored across both Chapters 4 and 5. For example, pupil participation in interschool sports was included in this study because it is likely to reflect PA performed outside of school hours better than pupil participation in school sport/PA clubs as examined in Chapter 4. Some variables were included again to assess whether relationships differed according to specific times (e.g., BMI z-score, active transport, and outdoor time), and once more correlates were chosen carefully based on the results of past pertinent research.

Further, a wider range of environmental correlates were included to gain a better idea of 'where and when' children are physically active. This was seen as important

to explore based on the results of the Report Card because although it was evident that there is sufficient provision of facilities, it could be that certain facilities or opportunities for PA are less appealing or conducive to PA compared to others.

As there has been a lack of research on correlates of time-specific PA among UK children, an exploratory approach was taken using unadjusted analyses first, including age and sex as potential correlates rather than covariates. This is because of the argument posed by Biddle and colleagues,[65] that relationships between sex and PA may have been exacerbated in the past, since they may differ according to specific aspects of PA.

Statement of Authorship

This declaration concerns the article entitled:									
Correlates of children's physical activity outside of school hours: results from ISCOLE-UK.									
Publication status (tick one)									
Draft manuscript		**Submitted**		**In review**	✓	**Accepted**		**Published**	
Publication details (reference)	Wilkie HJ, Standage M, Gillison FB, Cumming SP, Katzmarzyk PT. Correlates of children's physical activity outside of school hours: results from ISCOLE-UK. *BMC Public Health.*								
Candidate's contribution to the paper (detailed, and also given as a percentage).	**Formulation of ideas:** The candidate contributed considerably to the ideas for this paper. Candidate contribution = 90% **Design of methodology:** The candidate did not contribute to the design or methodology of the overall ISCOLE study, but the candidate selected the variables for analysis and chose the data analysis techniques required for the paper. Candidate contribution = 30% **Experimental work:** The candidate did not collect data until the final stages of the ISCOLE study but the candidate executed the statistical analysis. Candidate contribution = 60% **Presentation of data in journal format:** The candidate drafted and formatted the manuscript according to the journal requirements. All other authors provided edits and contributions to the paper. Candidate contribution = 80%								
Statement from Candidate	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature.								
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Data access statement: No additional data are available.

5.1 Abstract

Background: Correlates of children's PA may differ according to the time-specific period in question, yet research exploring this with UK children is lacking. Accordingly, the purpose of this study was to assess potential correlates of children's PA performed before school, after school, and on weekends across multiple levels of influence.

Methods: A cross-sectional design was employed and data were collected from 26 schools in South West England as part of the ISCOLE study. The analytic sample consisted of 406 children aged 9-11 years old, who provided valid data for all measures. Mean time spent in MVPA before and after school and on weekend days was assessed via accelerometers. Potential correlates were chosen *a priori* to include demographic, behavioural, home, neighbourhood, and school environmental factors.

Results: Boys and children using active means to get to school recorded more minutes of MVPA before school than girls and passive commuters respectively. Negative associations were observed between MVPA before school and parents' traffic-related safety concerns and having a TV in the child's bedroom. After school MVPA was positively associated with male sex, active transport, outdoor time after school, and access to a beach, lake, river, or stream and negatively associated with BMI z-score. Children of a high SES (indexed by high parental education) recorded less time in MVPA after school than those considered low SES. Male sex, active transport, and outdoor time on weekends were positively, and BMI z-score negatively, associated with weekend MVPA. Other correlates of weekend MVPA included access to playing fields/courts (positive), access to a large park (negative) and parents' crime-related safety concerns (negative).

Conclusions: Within this sample of UK children, PA participation outside school hours was associated with individual, home, and neighbourhood correlates; none pertaining to the school environment were found.

5.2 Background

PA is essential for healthy development and wellbeing across the lifespan.[1] Yet children's PA levels across England are low[2,3] and interventions designed to increase PA levels have only yielded small effects.[4] This is despite a large amount of past research on the correlates of PA, which can inform intervention strategies by exploring what might or might not promote PA participation.

Inconsistent results across studies within the extant literature have hindered our ability to understand which correlates are likely to be more important than others in terms of enhancing intervention efforts.[5-7] Methodological differences have likely contributed to these inconsistencies,[6] but another issue is the lack of specificity employed in previous research because overall measures of PA performed across the entire week have typically been assessed and examined.[5,8] Furthermore, several studies have covered correlates from only one or two environments. Thus, important associations may have been missed as PA is a complex and multidimensional behaviour, with its influences operating at several levels.[9] Consequently, there have been recent calls for a more contextualised approach to future research, whereby specific contexts (e.g., the time, type, and place) of PA behaviour are taken into consideration.[8] The focus of this study was on PA performed during specific times outside of school hours, when children typically have more choice over their behaviour.

The after school period, in particular, has been identified as a 'critical window' for promoting PA because PA participation during this time can make a significant contribution to total daily PA levels.[10] In addition, the largest differences in MVPA have been observed between active and inactive children during this period.[11] Evidence from the US, however, shows that youth are spending the majority of their time after school (> 90%) in sedentary or light intensity activity.[12] Equivalent data from the UK has shown that boys and girls spend more time engaged in screen-based pursuits after school than in any other behaviour.[13]

Children also tend to do less PA on weekends as opposed to weekdays.[14-17] In a recent longitudinal study that followed children over four years (i.e., from age 10 to 14 years), the largest declines in PA were observed on weekends.[18] Similar reductions in PA were reported before and after school, whereas no declines were observed during lesson time.[18] This is concerning because further reductions in PA may occur beyond school age, when lesson time PA is no longer present. It is therefore important to understand how we can increase PA during children's free time by exploring how and where they are active within specific periods outside of school hours (i.e., before/after school and on weekends).

According to a review of the literature, very little research has been carried out on the correlates of time-specific PA, and the majority of studies have been conducted among samples of US children.[19] McMinn and colleagues[20] published a study on UK children which explored potential familial/home environmental correlates of MVPA recorded after school and on weekend days. The period before school was not

examined and few correlates were found for weekend MVPA in comparison to MVPA after school. It was speculated that other correlates related to the wider environment might be associated with weekend MVPA since children potentially spend more of their time on weekends away from home.[20]

The purpose of this study was to extend the work by McMinn et al,[20] and explore correlates of children's PA outside of school hours, covering multiple domains within the socio-ecological model. In order to capture the whole of children's free time outside of school, we examined correlates of MVPA before school, MVPA after school, and MVPA on weekends.

5.3 Methods

5.3.1 Participants and Study Design

Data were collected from Bath and North East Somerset and West Wiltshire in England as part of a large international study (viz., ISCOLE[21]). Data collection took place from September 2011 to January 2013 across 26 schools during term time and pupils in Years 5 and 6, aged 9-11 years, were recruited.[21] Children were eligible to take part once informed parental consent and child assent was attained, and participants were included in the analysis if they had valid data for all measures. The study was approved by the University of Bath Research Ethics Approval Committee for Health (REACH).

5.3.2 Study Protocol

Detailed information regarding the ISCOLE protocol and overarching study has been published previously,[21] but here we describe the protocol as it pertains to the current work. During a visit to each school, anthropometric measurements from all participating children were collected by trained ISCOLE research staff. Participants also completed a Diet and Lifestyle Questionnaire to gather information on their engagement in specific PA behaviours (e.g., active transport). The children were provided with an accelerometer to wear for the following week, and two questionnaires were taken home for their parent/guardian to complete, including a Demographic and Health Questionnaire and a Neighbourhood and Home Environment questionnaire. Data on the school environment were also gathered via a questionnaire completed by a school administrator. All accelerometers and questionnaires were collected during a separate visit to the school and data were entered onto an online data management system.[21] Standardised procedures were

used throughout and rigorous training and quality control measures were followed to minimise bias and ensure data completeness across the 12 ISCOLE sites.[21]

5.3.3 Measures

5.3.3.1. Outcome Variables

Time spent in PA was measured objectively with an ActiGraph GT3X+ accelerometer (ActiGraph LLC, Pensacola, FL, USA), which participants wore at their waist for up to 7 consecutive days, following an initial familiarisation day.[21] A 24-hour wear time protocol was implemented in order to improve compliance, though participants were asked to take off the device for any water related activities.[21,22] A thorough explanation of the accelerometer protocol and treatment of the data has been provided elsewhere.[22] To summarise, nocturnal sleep and periods of waking non-wear time (any consecutive zero counts lasting ≥ 20 minutes[23]) were established first using a published automated algorithm.[24] Remaining minutes were classified as waking wear time, and participants with at least 10 hours of wear time per day on ≥ 4 days, including at least one weekend day, were considered to have valid data.[22] Evenson cut-points were used to define MVPA which encompassed any activity equating to ≥ 574 counts/15s.[25] The mean time spent in MVPA during the before school, after school and weekend periods was computed. Using information from each participating school regarding their start and end times, the before school segment was defined as the period from wake time until the start of the school day, whereas time after school was defined as the period from the school end time until the child's sleep onset. Both wake time and sleep onset were identified using the aforementioned algorithm.[24]

5.3.3.2. Potential Correlates

Potential correlates were chosen *a priori* based on the results of previous empirical research (e.g.,[19,20,26]) and covered multiple domains of the socio-ecological model, developed by Sallis et al,[9] including demographic, behavioural, home, neighbourhood, and school environmental variables. A description of all potential correlates, including the sources of measurement, has been provided in Table 5.1.

Table 5.1 Description of potential correlates

Domain	Variable	Measurement	Description/Data Handling
Demographic	Age	Parent D&H	Participants' decimal age at the time of data collection, calculated from Date of Birth.
	Sex	Parent D&H	Male/Female
	BMI z-score	Anthropometry	Anthropometric measurements taken and BMI calculated using: weight (kg)/height (m)^2 Age and sex-specific BMI z-scores computed using the World Health Organization growth reference.[27]
Behavioural	Screen time on school and weekend days	Child D&L	Children asked how many hours they watched TV on a school and weekend day in the last week.[28] Responses: 0, < 1, 1, 2, 3, 4 or 5+ hours. Participants asked the same in relation to video/computer games and other recreational computer use.[28] Overall screen time score computed (sum of TV and computer scores) for school and weekend days separately. Due to non-linearity with the outcomes, screen time on school and weekend days was dichotomised according to whether children engaged in ≤ 2.0 hours or > 2.0 hours per day.[29]
	Active transport to school	Child D&L	Participants asked about the main part of their journey to school in the last week. Responses categorised as 'active' (walking, bicycle, roller-blade, skateboard or scooter) and 'passive' (bus, train, tram, underground or boat, car, motorcycle or moped).[30]
	Outdoor time before school, after school and on weekend days	Child D&L	Children asked how much time they spent outside before school, after school before bedtime, and on a weekend day in the last week; responses: < 1, 1, 2, 3, 4 or 5+ hours. Participants were dichotomised into one of two groups for each time period as follows: 1) Before school: < 1 hour versus ≥ 1 hour; 2) After school: < 2 hours versus ≥ 2 hours; 3) Weekend: < 3 hours versus ≥ 3 hours.
Home Environment	SES	Parent D&H	Highest level of parental education attained: Low: GCSEs or less; Average: A Levels/equivalent; High: University (Bachelor's or Postgraduate) degree.
	TV in the child's bedroom	Child D&L	Yes/No response
Neighbourhood Environment	Access to PA facilities	Parent NHEQ	Time to walk from home to 8 different PA facilities (e.g., playing fields, parks, etc.): 1-5 min; 6-10 min; 11-20 min; 21-30 min; 31+ min; Don't know.[31] Responses categorised as ≤ 20 min or > 20 min* to examine relationships for specific facilities. The total number of facilities within a 20 minute walk also computed, to create an overall access to PA facilities variable.

Continued

	Crime-related safety concerns	Parent NHEQ	Five items regarding crime safety perceptions in the neighbourhood.[31] Responses coded on a scale of 1-4, from 'strongly disagree' to 'strongly agree'. Mean score of items computed (participants missing data for more than one item not included); higher scores indicate greater parental concerns.
	Traffic-related safety concerns	Parent NHEQ	Five items regarding traffic safety perceptions in the neighbourhood.[31] Responses coded on a scale of 1-4, from 'strongly disagree' to 'strongly agree' (3 items required reverse coding). Mean score of items computed (participants missing data for more than one item not included); higher scores indicate greater parental concerns.
School Environment	School provision of a late bus service	SEQ	Does your school offer a late bus/transportation service to students who participate in extra-curricular activities? Yes/No response.[32]
	Student access to outdoor facilities permitted out of hours	SEQ	Outside of school hours, does your school permit regular student access to outdoor facilities (e.g., playing fields, paved activity areas)? Yes/No response.[32]
	Student participation in interschool sports	SEQ	What percent of pupils participate in interschool sports? Three category variable created: Not available or < 10%; 10-24%; ≥ 25%.[32]
	School provision of a car free zone	SEQ	Does your school promote active transport to/from school by designating a 'car free zone'? Yes/No response.[32]

*Don't know response included in > 20 min category.[33]

BMI, body mass index; D&H, Demographic and Health Questionnaire; D&L, Diet and Lifestyle Questionnaire; GCSE, General Certificate of Secondary Education; NHEQ, Neighbourhood and Home Environment Questionnaire; PA, physical activity; SEQ, School Environment Questionnaire; SES, socioeconomic status; TV, television.

5.3.4 Statistical Analysis

All analyses were conducted with SAS Studio 3.5 (SAS Institute Inc., Cary, NC, USA, 2012-2016). Descriptive statistics of the analytic sample were computed, and these were compared with excluded participants using independent samples t-tests and chi-square tests for continuous and categorical variables, respectively. Unadjusted analyses exploring the relationship between each independent variable and the three outcomes (MVPA before school, MVPA after school, and MVPA on weekend days) were conducted first using 'PROC MIXED'. Variables with a p value of < 0.10 were included in multiple regression models where the backward elimination approach was used. Non-significant variables with the highest p value were removed one by one until only variables with a significant relationship ($p<0.05$) were left; these were considered to be significant correlates of time-specific PA. Checks for potential multicollinearity were performed first; this was only problematic when both access to specific facilities and overall access to facilities were associated with the same outcome (because overall access was computed from the sum of specific facilities available within a 20 minute walk). Where this was the case, separate multiple regression models were created, including overall access in one model, and access to specific facilities in another. Despite this, overall access did not remain significant and was removed from the adjusted model. Consequently, there was no difference to the other results, and the final regression models that included access to specific facilities, some of which did remain significant, are presented. It was also evident from screening the data that an extreme outlier was present, which exerted significant influence on some of the relationships being tested, particularly for MVPA after school. This participant was therefore excluded from the analytic sample. Mean accelerometer wear time before school, after school, and on weekends was included as a covariate in all analyses for each respective outcome, and schools were treated as random effects to account for potential clustering at the school-level. Age and sex were treated as potential correlates instead of covariates due to the lack of time-specific research in the UK supporting the premise that age and sex differences are present during particular time-segments outside of school hours.

5.4 Results

A total of 541 pupils consented to take part in ISCOLE at the UK site. Eight participants withdrew and 54 participants were removed as they did not have valid accelerometry data. After excluding those with missing data for any variables

included in the analysis (n=72), as well as the extreme outlier (n=1), the analytic sample consisted of 406 children. Excluded participants had a significantly higher BMI z-score and performed less MVPA over the weekend. No other differences were found for age, sex, MVPA before or after school, or accelerometer wear time. The intra-class correlation showed that 17% of the variability in MVPA before school, 12% of the variation in MVPA after school, and 8% of the variability in MVPA recorded over the weekend was attributed to the school level. Thus, 83%-92% of the variation occurred at the individual level.

Descriptive statistics of the analytic sample are presented in Table 5.2. The mean age of all participants was 10.9 years (± 0.4) and 43% of the sample were boys. Nearly half of participants had parents with a 'high' education (i.e., hold a University degree). The mean time spent in MVPA before school, after school, and on weekend days was 8.0 (± 5.1), 30.5 (± 13.2) and 57.7 (± 30.3) minutes/day, respectively. Boys recorded more minutes of MVPA than girls across all time periods.

Table 5.2 Descriptive characteristics for the total sample and by sex

	Mean (SD) or N (%)		
	Total Sample (n=406)	**Boys (n=174)**	**Girls (n=232)**
Age	10.9 (0.4)	10.9 (0.4)	10.9 (0.5)
BMI	18.4 (2.9)	18.0 (2.6)	18.6 (3.2)
BMI z-score	0.4 (1.1)	0.4 (1.0)	0.4 (1.1)
SES (Highest parental education level)			
Low (GCSEs or less)	113 (27.8)	40 (23.0)	73 (31.5)
Average (A Levels or equivalent)	102 (25.1)	45 (25.9)	57 (24.6)
High (University degree)	191 (47.0)	89 (51.2)	102 (44.0)
Mean time in MVPA before school (min/day)	8.0 (5.1)	8.8 (5.6)	7.5 (4.6)
Mean time in MVPA after school (min/day)	30.5 (13.2)	33.2 (14.9)	28.5 (11.4)
Mean time in MVPA on weekends (min/day)	57.7 (30.3)	67.3 (33.4)	50.5 (25.5)
Mean waking wear time before school (min/day)	99.6 (32.9)	102.6 (33.8)	97.3 (32.0)
Mean waking wear time after school (min/day)	380.4 (47.1)	381.8 (47.5)	379.3 (46.8)
Mean waking wear time on weekends (min/day)	812.0 (81.3)	825.7 (81.5)	801.7 (79.7)

BMI, body mass index; GCSE, General Certificate of Secondary Education; MVPA, moderate-to-vigorous intensity physical activity; SES, socioeconomic status.

5.4.1 Unadjusted Analyses

Results from the unadjusted analyses are shown in Table 5.3. Male sex, active transport to school, outdoor time (all positive), and BMI z-score (negative) were associated with all three MVPA outcomes. As for the home environment, SES was only associated with MVPA performed after school (high SES children did less MVPA after school than their low SES counterparts), while the presence of a TV in the child's bedroom was negatively associated with MVPA before school. In terms of access to specific facilities, children who lived within a 20 minute walk of playing fields/courts recorded more minutes of MVPA during all time periods than those who lived further away from such facilities. Access to other facilities displayed an association with one or two outcomes, and with the exception of access to a large park and its association with weekend MVPA, these relationships were in a positive direction. Overall access to PA facilities was associated with MVPA before and after school but not with weekend MVPA. A negative relationship between crime-related safety concerns and all outcomes was found, whereas this was only the case for MVPA before school and traffic-related safety concerns. Only one school-level variable (provision of a car free zone) was included in the adjusted analysis for weekend MVPA. Although no association was observed across all three levels for pupil participation in interschool sports, it is noteworthy that a significant difference was observed between the highest and lowest categories for both after school and weekend MVPA. Children who attended schools with ≥ 25% of pupils engaged in interschool sports recorded 4.83 fewer minutes of MVPA after school, and 10.50 fewer minutes of MVPA on weekend days, than those who attended schools with < 10% of pupils engaging in such activity.

5.4.2 Adjusted Analyses

Final regression models are displayed in Table 5.4. Boys achieved 1.28, 5.37, and 13.88 more minutes of MVPA than girls before school, after school, and on weekend days, respectively. Active transport to school was also significantly associated with all MVPA outcomes. That is, children who walked, cycled, or used other active means to get to school recorded more minutes of MVPA than those using passive forms of transport across all time periods. More time spent outdoors was associated with more minutes of MVPA after school and on weekend days, while a negative relationship was found for BMI z-score with both of these time periods. Children who reported having a TV in the bedroom recorded significantly less MVPA before school than those without one, while participants from a high SES background recorded less MVPA after school than their peers with a low

Table 5.3 Unadjusted analyses showing simple relationships among potential correlates and MVPA before school, MVPA after school and weekend MVPA (n=406): beta-coefficients, standard error and p values

	MVPA Before School		MVPA After School		Weekend MVPA	
	β (SE)	***p***	**β (SE)**	***p***	**β (SE)**	***p***
Demographic						
Age	0.39 (0.65)	.551	1.07 (1.74)	.537	-4.03 (3.88)	.300
Male sex	1.27 (0.47)	**.007**	5.32 (1.25)	**<.0001**	16.10 (2.88)	**<.0001**
BMI z-score	-0.45 (0.21)	**.037**	-2.04 (0.58)	**.001**	-4.60 (1.35)	**.001**
Behavioural						
≤ 2 hours of screen time on school and weekend days*	-0.19 (0.47)	.682	-0.06 (1.29)	.964	4.99 (3.39)	.142
Active transport to school	4.00 (0.46)	**<.0001**	3.82 (1.35)	**.005**	6.07 (3.11)	**.052**
Outdoor time: before school (≥ 1h); after school (≥ 2h); weekends (≥ 3h)†	1.09 (0.63)	**.081**	4.07 (1.27)	**.002**	8.07 (2.98)	**.007**
Home environment						
SES (highest parental education level)						
Low (GCSEs or less)	Ref	.691	Ref	**.079**	Ref	.714
Average (A Levels or equivalent)	-0.55 (0.64)	.394	-2.45 (1.75)	.163	-1.15 (4.04)	.775
High (University degree)	-0.32 (0.58)	.579	-3.58 (1.59)	**.025**	1.76 (3.64)	.629
Presence of a TV in the child's bedroom	-1.52 (0.48)	**.002**	-1.09 (1.35)	.420	-1.81 (3.05)	.553
Neighbourhood environment						
Access to specific PA facilities within a 20 min walk from home:						
Indoor recreation/exercise facility	1.35 (0.48)	**.005**	0.83 (1.32)	.532	-0.59 (3.03)	.845
Bike/hiking/walking trails/paths	0.61 (0.55)	.274	0.21 (1.52)	.891	4.41 (3.49)	.207
Other playing fields/courts (football/tennis/skate park etc.)	1.10 (0.53)	**.037**	2.42 (1.44)	**.094**	7.82 (3.30)	**.018**
Large public park	0.87 (0.47)	**.064**	-0.39 (1.29)	.760	-6.67 (2.94)	**.024**

Continued

Public playground with equipment	1.01 (0.54)	**.063**	1.39 (1.49)	.354	0.22 (3.43)	.949
School with recreation facilities open to the public	0.72 (0.55)	.191	2.34 (1.51)	.123	4.29 (3.47)	.217
Beach, lake, river, or stream	0.59 (0.47)	.205	3.12 (1.28)	**.015**	2.55 (2.94)	.386
Basketball court	0.98 (0.48)	**.042**	1.37 (1.32)	.302	5.34 (3.00)	**.076**
Overall access to PA facilities‡	0.38 (0.11)	**.001**	0.59 (0.32)	**.066**	0.80 (0.73)	.276
Crime-related safety concerns	-0.97 (0.37)	**.009**	-1.70 (1.02)	**.096**	-9.30 (2.31)	**<.0001**
Traffic-related safety concerns	-2.09 (0.45)	**<.0001**	-0.53 (1.24)	.668	1.42 (2.85)	.619
School environment						
School provision of a late bus service	0.98 (1.41)	.488	-0.66 (3.35)	.845	-8.36 (6.46)	.197
Student access to outdoor facilities permitted out of school hours	-0.19 (1.05)	.857	-2.01 (2.49)	.419	-4.65 (5.05)	.358
% of students that do interschool sports						
< 10%	Ref	.620	Ref	.132	Ref	.121
10-24%	1.08 (1.29)	.401	-1.93 (2.70)	.475	-7.68 (5.64)	.174
≥ 25%	0.06 (1.16)	.960	-4.83 (2.45)	**.049**	-10.50 (5.15)	**.042**
School provision of a car free zone	0.05 (1.01)	.962	-0.77 (2.39)	.748	-7.65 (4.63)	**.099**

*Estimates for MVPA before and after school refer to the relationships with school day screen time, while the estimate for weekend MVPA refers to the relationship with weekend screen time.

†Estimates for MVPA before school, MVPA after school and weekend MVPA refer to the relationships with outdoor time before school, outdoor time after school, and outdoor time on weekends, respectively.

‡Sum of PA facilities within a 20 minute walk from home.

Schools treated as random effects in all models, adjusting for mean accelerometer wear time only.

BMI, body mass index; GCSE, General Certificate of Secondary Education; MVPA, moderate-to-vigorous intensity physical activity; PA, physical activity; Ref, reference category; SES, socioeconomic status; TV, television.

Bold font indicates p<0.10.

education; no significant difference was seen between the low and average education levels. Access to a beach, lake, river, or stream was positively associated with after school MVPA, whereas access to playing fields/courts (positive) and access to a large park (negative) were significantly associated with weekend MVPA. Traffic-related safety concerns were negatively associated with MVPA conducted before school while crime-related safety concerns were negatively related to MVPA performed over the weekend.

Table 5.4 Final regression models showing correlates of MVPA before school, MVPA after school and weekend MVPA (n=406): beta-coefficients, standard error and p values

	β (SE)	***p***
MVPA Before School		
Male sex	1.28 (0.42)	.002
Active transport to school	3.62 (0.45)	<.0001
Presence of a TV in the child's bedroom	-1.13 (0.44)	.010
Traffic-related safety concerns	-1.72 (0.41)	<.0001
MVPA After School		
Male sex	5.37 (1.21)	<.0001
BMI z-score	-1.97 (0.57)	.001
Active transport to school	2.85 (1.31)	.030
Outdoor time after school (≥ 2 hours/day)	3.35 (1.22)	.006
SES (highest parental education level)		
Low (GCSEs or less)	Ref	.030
Average (A Levels or equivalent)	-1.68 (1.68)	.319
High (University degree)	-3.98 (1.53)	.010
Access to a beach/lake/river/stream (≤ 20 min walk from home)	2.75 (1.23)	.026
Weekend MVPA		
Male sex	13.88 (2.79)	<.0001
BMI z-score	-3.63 (1.27)	.005
Active transport to school	6.13 (2.93)	.037
Outdoor time on weekends (≥ 3 hours/day)	6.55 (2.78)	.019
Access to other playing fields/courts (≤ 20 min walk from home)	8.16 (3.25)	.013
Access to a large public park (≤ 20 min walk from home)	-8.38 (2.92)	.004
Crime-related safety concerns	-6.59 (2.21)	.003

Final mutually adjusted models for each outcome variable are presented (i.e., all independent variables included simultaneously). Schools were treated as random effects and mean accelerometer wear time was included as a covariate in all models.

BMI, body mass index; GCSE, General Certificate of Secondary Education; MVPA, moderate-to-vigorous intensity physical activity; Ref, reference category; SES, socioeconomic status; TV, television.

5.5 Discussion

The aim of this study was to explore correlates of children's MVPA performed outside of school, using a socio-ecological framework that embraces potential correlates of MVPA at multiple levels of influence. Demographic and behavioural correlates, as well as those pertaining to the home and neighbourhood environments, were associated with MVPA during children's free time. In contrast, no significant associations were found in relation to the school environment.

Significant associations for demographic and behavioural correlates were found for all MVPA time periods, which highlights the importance of accounting for individual and behavioural differences with regards to MVPA in general. In particular, significant associations for sex and active transport were found for all three MVPA time segments. Boys and children who actively commuted to school recorded more MVPA than girls and passive commuters respectively, and the largest differences were observed on weekends. Boys have consistently reported higher overall PA levels than girls,[6,14,34-37] and similar findings have been reported elsewhere for after school and weekend PA specifically.[10,19,26] As for active transport to school, other research has shown that this behaviour is positively associated with PA,[38-40] including MVPA before school.[41] It has been argued that children who actively commute to school may be more active in general,[40] which is supported by research showing that children who walk or cycle to school tend to engage in other walking or cycling.[39,42] This could explain the positive association observed for weekend MVPA in the current study, although it is unknown as to whether active travel was a matter of choice or necessity. Thus, further work is needed to explore such mechanisms in more detail.

Our results also suggest that children with higher BMI values may be less active during discretionary periods (after school and on weekends), which is consistent with previous literature,[11,19] and strategies to promote time outdoors after school and on weekends may prove effective, given that outdoor time in general has been identified as a consistent correlate of PA in several reviews.[5,6,43] Yet, time outdoors is likely to be associated with environmental factors (e.g., space to play, safety concerns, etc.) in its own right.[5] Nevertheless, interventions targeting at risk groups (girls and children with higher BMI levels) and strategies which promote more time in specific behaviours (active travel and time outdoors) are likely to be of benefit.

In terms of the home environment, the results for SES concur with those of McMinn and colleagues.[20] That is, parental education was negatively associated with after school but not weekend MVPA.[20] No association was found for MVPA before school either in the current study. Similar results have been reported in other UK research exploring SES and overall PA participation; higher parental education was associated with lower PA among children living in rural areas,[34] and low maternal education was associated with higher PA among participants of the MCS.[44] It was suggested that children from a high SES background may be less likely to use active transport,[34] or they could be spending more time studying/doing homework,[45] which will likely be pertinent after school. Additionally, although low SES children are less likely to engage in formal/structured PA (e.g., organised sport), they may compensate for this through informal PA.[46] Low SES participants in our sample may have been engaging in more informal PA after school, and the lack of an association for weekend MVPA may reflect engagement in organised sport among high SES participants.[20,47] A deeper understanding of the types of activities that children from different socioeconomic backgrounds typically engage in during specific times is needed to support these ideas, and a wider age range of participants should be assessed given that contrasting and potentially stronger associations may exist among adolescents.[43]

The presence of a TV in the child's bedroom was also assessed and a significant negative relationship with MVPA before school only was found. Reasons for this are unknown, although it could be that such children are simply watching more TV in the morning, or other mechanisms pertaining to sleep patterns,[48,49] and subsequently their wake time, could be involved which warrants further research.

Significant relationships were present for correlates pertaining to the neighbourhood environment and weekend MVPA, which provides some initial support for the argument that factors away from home may be more influential during this time segment.[16,20] Access to playing fields/courts (e.g., football, tennis, skate park, etc.) was positively associated with all MVPA outcomes in the unadjusted analysis, but this remained significant in the adjusted model for weekend MVPA only. Conversely, access to a large public park was negatively associated with weekend MVPA. This differs to past research showing a positive relationship between access to parks/playground areas and children's PA,[26,34,50,51] though children used small parks more often than large parks in a US study.[52] It is plausible to suggest that children who use playing fields or courts go with the intention and purpose of doing

PA (i.e., they may take a football, play tennis or go skate boarding, etc.), whereas large parks may be somewhere that children go to with parents on weekends and used for lighter intensity PA (e.g., for walks or a family picnic). Despite this, green space and gardens have been positively associated with PA in past work,[53,54] and more research that also considers the quality of such facilities utilising objective measures is needed.

As for neighbourhood safety concerns, little support for a relationship with children's PA has been found in previous studies.[6,19,43,44,51,55,56] However, crime- and traffic-related safety concerns are rarely distinguished from one another according to Ding et al,[55] and again, the majority of studies have explored overall PA levels as opposed to time-specific PA in this particular area.[51] Crime-related safety concerns were negatively associated with weekend MVPA in the present work, while a significant negative relationship was observed between traffic-related safety concerns and MVPA before school. It could be speculated that the weekend may present greater crime-related concerns among parents seen as children have the potential to play outdoors for longer outside the immediate home environment. As for traffic-related concerns, they may be more evident before school because of the school commute, and our results showed that such concerns are apparent regardless of the child's travel mode to school. Overall, these findings indicate that different parental-perceived safety concerns may differ according to the time of week and essentially the context of children's PA behaviour.

Although the school-level variables investigated in this study were chosen for their potential to influence MVPA outside of school hours, none had a significant relationship with MVPA before or after school or on weekends. This was despite the fact that a large proportion of the variability in MVPA during these times occurred at the school level (8%-17%). Given that there is a lack of research on school-level variables,[43] more work is needed on how schools can positively influence PA attained out of school hours, particularly since multi-component interventions which combine school and family based strategies may provide the most success.[57]

A key strength of the current study was the use of time-specific PA outcomes and the inclusion of correlates from multiple domains. The three MVPA outcome variables were objectively assessed which provides a more robust measure of MVPA than self-reported methods, but while providing information regarding intensity, does not provide information on the types of PA being performed. Other limitations include the cross-sectional study design, thus the direction of causality

cannot be inferred, and our data do not provide an ethnically diverse sample, as the majority of participants were White British. This limits our ability to explore how correlates differ according to specific ethnic groups, and some of our findings may not generalise to other populations within the UK. Furthermore, stronger evidence has been found for neighbourhood correlates of PA in studies that utilised objective measures of the built environment.[55] It is therefore possible that this study was limited by the self-reported nature of the built environment items. The results for school-level variables must be treated with caution because data were collected on 26 schools only, thus there may have been inadequate power to detect significant differences. It is therefore wise not to assume that school PA policies do not work due to the findings reported.

5.5.1 Conclusions

In conclusion, strategies that target at risk groups that encourage active travel and outdoor time outside school hours are needed. Facilities which include features that are conducive to PA (e.g., playing fields, tennis courts, football grounds, skate parks, etc.), that are close to residential areas and provide a safe but informal environment may help to promote MVPA among children, although further empirical work is needed to support this premise.

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Chapter 5 Closing Commentary

This study has provided more contextual information because the results show which correlates are associated with MVPA during particular times, when we should intervene to promote more PA. For example, traffic-related safety concerns appeared to be more prominent before school whereas crime-related safety concerns were associated with MVPA over the weekend, and facilities which have features designed to promote free active play may help. Although more research is needed to support these findings, the results emphasise how important it is to look at PA research from a more applied and contextualised approach because of the additional information that can be gleaned from using such techniques.

A composite measure of ST was assessed because no association was found with MVPA in the former study when TV viewing and computer use were assessed separately (with the exception of computer use and MPA specifically). However, no differences were found in MVPA outside of school hours between those who met ST guidelines on school and weekend days specifically and those who did not achieve such guidelines. This is despite arguments that the displacement hypothesis may be more evident during such times (i.e., after school and on weekends).[65] A further argument is that there may be underlying differences, in relationships between ST and PA, between specific groups of children. This was therefore kept in mind for the following Chapters, especially given the arguments posed earlier regarding the need for specific sedentary behaviour guidelines in the UK.

No significant associations related to the school environment were found, suggesting that those explored in Chapter 4 may be more important or they could have been related to PA inside of school hours. There was also a potential lack of power and there is a need for larger scale studies that adopt multilevel modelling techniques to see how the school environment can be targeted to positively influence children's PA both inside and outside of school hours.

CHAPTER 6

The home electronic media environment and parental safety concerns: relationships with outdoor time after school and over the weekend among 9-11 year old children

Chapter 6 Opening Commentary

As informal PA is more likely to occur outdoors,[104] and given the cover story used for the Report Card in Chapter 3, outdoor time was assessed in the penultimate Chapter of the thesis so as to examine a specific type of PA behaviour more closely. Another reason for choosing time spent outdoors as the outcome variable is that this was positively associated with PA in both Chapters 4 and 5 and less research has been conducted on outdoor time as opposed to active transport. Furthermore, data on active transport to school only was collected and this was associated with weekend MVPA in the previous study which suggests these data are capturing PA in general. Data on sport participation were deemed insufficient because participants were asked whether they had played sport in the last 12 months using a simple 'Yes' or 'No' question, whereas more contextual information for time outdoors during discretionary periods was available.

Time spent outdoors after school and on weekends was therefore assessed; time outdoors before school was not because it was not identified as a correlate of MVPA before school in the former study. The 2016 Report Card highlighted the lack of time children spend outdoors today and some of the potential reasons for this included increased availability of screen-based media and parental safety concerns. As such, the purpose of this study was to examine such relationships in detail. A further development at this stage was to explore interactions by sex and SES to assess whether any of the relationships differed according to specific groups.

Statement of Authorship

This declaration concerns the article entitled:									
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Candidate's contribution to the paper (detailed, and also given as a percentage).	**Formulation of ideas:** The candidate formulated all ideas for this paper. Candidate contribution = 100% **Design of methodology:** The candidate had no contribution to the study design or methodology employed for the overall ISCOLE study, but the candidate predominantly contributed to the identification of variables of interest for the paper and techniques for data analysis. Candidate contribution = 30% **Experimental work:** The candidate did not contribute to the data collection until the final stages of the study but the candidate was responsible for data analysis. Candidate contribution = 60% **Presentation of data in journal format:** The candidate was responsible for drafting the manuscript and formatting it in line with journal specifications. The remaining authors provided edits and comments to the paper. Candidate contribution = 80%								
Statement from Candidate	This paper reports on original research I conducted during the period of my Higher Degree by Research candidature.								
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Data access statement: No additional data are available.

6.1 Abstract

Background: Time spent outdoors is associated with higher PA levels among children, yet it may be threatened by parental safety concerns and the attraction of indoor sedentary pursuits. The purpose of this study was to explore the relationships between these factors and outdoor time during children's discretionary periods (i.e., after school and over the weekend).

Methods: Data from 462 children aged 9-11 years old were analysed using generalised linear mixed models. The odds of spending > 1 hour outdoors after school, and > 2 hours outdoors on a weekend were computed, according to demographic variables, screen-based behaviours, media access, and parental safety concerns. Interactions with sex and SES were explored.

Results: Boys, low SES participants, and children who played on their computer for < 2 hours on a school day had higher odds of spending > 1 hour outside after school than girls, high SES children and those playing on a computer for ≥ 2 hours, respectively. Counterintuitive results were found for access to media devices and crime-related safety concerns as both of these were positively associated with time spent outdoors after school. A significant interaction for traffic-related concerns*sex was found; higher road safety concerns were associated with lower odds of outdoor time after school in boys only. Age was associated with weekend outdoor time, which interacted with sex and SES; older children were more likely to spend > 2 hours outside on weekends but this was only significant among girls and high SES participants.

Conclusions: Our results suggest that specific groups of children are less likely to spend their free time outside, and it would seem that only prolonged recreational computer use has a negative association with children's outdoor time after school. Further research is needed to explore potential underlying mechanisms, and parental safety concerns in more detail.

6.2 Background

Time spent outdoors has consistently been associated with higher PA levels,[1-7] and in a recent position statement, put forward by Tremblay and colleagues,[8] active outdoor play in the natural environment was recognised as a fundamental component of children's health and development. Not only is there more space for children to be physically active outdoors,[9] but access to sedentary pursuits is also minimised because activities such as TV viewing and playing computer games are

usually performed indoors.[7] It is, therefore, not surprising that children engage in significantly more PA outside the home rather than when they are indoors.[9-11]

Despite the benefits of outdoor play, research suggests that children have less freedom to play outside than they did in previous generations.[8,12,13] Many parents and grandparents cite that children no longer play traditional games or know how to ride a bike, both of which were frequent pastimes in their own childhood.[14] According to qualitative data,[15,16] previously reported barriers to outdoor play have included safety concerns, a lack of time, and greater pressure on academic study, as well as access to digital entertainment in the home. However, there is little support in the literature for an association between safety perceptions and children's PA,[5,12,17,18] and a negative, but weak, relationship was observed between screen-based behaviours and PA in a meta-analysis.[19] The authors concluded that the effect is therefore unlikely to be clinically relevant.[19]

A key criticism of past work is that general measures of overall PA tend to be assessed,[4,17] as opposed to certain types of PA performed during specific times.[20] In terms of the extant literature on time spent outdoors specifically, which is positively associated with PA,[2,3,21] overall measures of this behaviour have also been explored (e.g.,[22-24]). Though it may be that screen-based pursuits are more likely to compete for children's time outdoors after school or on weekends, when access to media-based entertainment is likely to be more prominent.[4] This notion is supported by two Australian studies; one found that the majority (78%) of time after school was spent indoors among 5-7 year olds,[9] while the other reported that this period contributed to 84% of children's daily ST among a larger sample of 8-9 year olds.[25] Furthermore, different aspects of parental perceptions of safety, such as traffic- and crime-related concerns, are rarely considered separately.[18] Thus, important relationships may have been missed in previous research because associations may differ between the two.

Consequently, the purpose of this study was to explore the relationships between indoor sedentary pursuits (specifically TV viewing, recreational computer use, and access to home electronic media devices), and parental perceived crime- and traffic-related safety concerns, with outdoor time after school and over the weekend. Given potential differences between boys and girls and socioeconomic groups, highlighted in past research,[6,26] we also tested for interactions with sex and SES.

6.3 Methods

6.3.1 Participants

Children in Years 5 and 6 (age 9-11 years) at schools across Bath and North East Somerset and West Wiltshire were recruited as part of the ISCOLE study.[27] Parental consent and child assent were obtained from all participants prior to data collection, which took place from September 2011 to January 2013 during term time. Ethical approval was granted from the University of Bath Research Ethics Approval Committee for Health (REACH).

6.3.2 Measures

6.3.2.1. Outdoor time

Participants completed a Diet and Lifestyle Questionnaire,[27] whereby they were asked how much time they spend outside 'on a school day after school before bedtime', and 'on a weekend day'. Six response options were available: '< 1 hour'; '1 hour'; '2 hours'; '3 hours'; '4 hours'; '5 or more hours'. A large amount of variation exists in the literature with regards to how time spent outdoors is expressed. In many studies, this behaviour has been dichotomised but different criteria have been applied to govern 'low' and 'high' amounts of time spent outdoors (e.g., 'low' amounts of time outdoors have been classified as < 0.5 hours/day[28]; < 1 hour/day[6]; < 2 hours/day[29,30] and ≤ 2 hours/day[24]). As such, we decided to conduct a frequency analysis, akin to Stone and Faulkner,[6] and chose the following categories for outdoor time after school: ≤ 1 hour/day versus > 1 hour/day, and for weekend outdoor time: ≤ 2 hours/day versus > 2 hours/day. Although different categories were chosen for after school and weekend outdoor time, these criteria were deemed as suitable given that there is more free time available over the weekend, and we wanted to capture differences for those spending several hours outdoors. A similar approach has been applied previously by Cleland et al,[31] who used different criteria for different seasons, as more time was spent outside during warmer months than during cooler months.

6.3.2.2. Screen Time

Participants also responded to four questions from the Youth Risk Behavior Surveillance System regarding the time spent watching TV and playing on a computer on school and weekend days specifically.[32] Available options included: 'I

did not watch TV/play video or computer games or use a computer other than for school work on school/weekend days'; '< 1 hour'; '1 hour'; '2 hours'; '3 hours'; '4 hours'; and '5 or more hours'. Children were categorised into high, medium, and low ST groups based on the following criteria: school day TV viewing: < 2, 2, and ≥ 3 hours/day; weekend TV viewing: < 2, 2-3, and ≥ 4 hours/day; school and weekend recreational computer use: None, < 2, and ≥ 2 hours/day. These categories were chosen in line with ST recommendations,[33] previous research,[34,35] and based on a frequency analysis of the current data.

6.3.2.3. Home electronic media environment

A questionnaire was also administered to the child's parent(s)/guardian(s),[27] which included six items from the Neighborhood Impact on Kids study survey,[36] regarding their child's access to specific electronic devices. Three related to whether their child had the following items in his/her bedroom: 1) a computer; 2) a TV; and 3) a video game system (non-hand held; Playstation, Xbox etc.). The remaining three items asked if their child had use of the following devices, not restricted to their bedroom: 1) a mobile phone or 2-way radio (walkie-talkie); 2) music systems (iPod, stereo, radio, etc.); and 3) hand-held videogame players (Game Boy, DS etc.). Parents responded either 'yes' or 'no' to each item. An overall 'media access' score was computed by summing the total number of devices that each child had access to. Participants were then split into one of three media access categories using the following criteria: low (access to 1 or no devices), average (access to 2-4 devices), and high (access to 5 or 6 devices). These categories were chosen based on the premise that 8-11 year olds, across the UK, own an average of 3 devices.[37]

6.3.2.4. Parental Safety Concerns

Data were also obtained from parents/guardians on their perceptions of safety concerns within the area where they live. Items were adapted from the Neighbourhood Environment Walkability Scale for Youth,[38] which consists of 5 items assessing crime-related safety concerns (e.g., 'I'm afraid of my child being taken or hurt by a stranger on local streets') and 5 items pertaining to traffic-related safety concerns (e.g., 'Most drivers go faster than the posted speed limits'). Each item included a 4-point Likert Scale (0-3) ranging from 'Strongly Disagree' to 'Strongly Agree'. The mean of available items was computed for those with responses to at least 4 of the items in each subscale; higher scores represent greater concerns.

6.3.2.5. Demographic Variables

Parents/guardians were also asked to provide information on their highest educational attainment in addition to their child's date of birth and gender. Age at the time of data collection was calculated from their date of birth. The highest parental education level was used as an indicator of SES; participants were classified as having either a high (A Levels or University Degree) or low (GCSEs or less) SES.

6.3.3 Statistical Analysis

SAS Studio 3.5 (SAS Institute Inc., Cary, NC, USA, 2012-2016) was used for all analyses. Participants with missing data for any variables were not included in the analytic sample. Descriptive statistics were computed for the total sample and by sex, and compared between those included and excluded using an independent samples t-test for continuous variables and chi-square tests for categorical variables. Generalised linear mixed models were employed for the main analysis using the GLIMMIX procedure, and results are presented as Odds Ratios (OR). Schools were treated as random effects in all models given the study design to adjust for potential clustering at the school level (ICCs: 0.09 and 0.03 for after school and weekend outdoor time, respectively). Simple associations were tested first, exploring the relationship between each independent variable and outcome variables, adjusting for covariates (age, sex, and SES) only. All variables were then entered into a mutually adjusted model; checks for multicollinearity were performed and no problems were identified. Finally, interactions with sex and SES were explored, as were relationships between specific media devices and each outcome variable.

6.4 Results

Consent was obtained from 541 participants but following eight withdrawals, and exclusion of those with invalid data, the analytic sample was comprised of 462 participants with complete data. No significant differences were found in terms of age, sex, outdoor time after school or outdoor time on weekends between those included and excluded from the analysis. Descriptive statistics are displayed in Table 6.1. The average age of participants was 10.9 (± 0.5) years and a higher proportion of children had parents with a high, versus low education level (71% vs.

29%). Over half (52.2%) of the analytic sample reported spending time outdoors for > 1 hour after school and 61.9% spent > 2 hours outside on a weekend.

Table 6.1 Descriptive characteristics of the analytic sample for all participants and by sex: Mean (SD) or %

	Total Sample (n=462)	**Boys (n=208)**	**Girls (n=254)**
Age	10.9 (0.5)	10.9 (0.4)	10.9 (0.5)
SES (Highest parental education)			
Low (GCSEs or less)	29.0	24.5	32.7
High (A Levels/University Degree)	71.0	75.5	67.3
Outdoor Time			
After school (> 1 h/d)	52.2	55.3	49.6
Weekend (> 2 h/d)	61.9	64.4	59.8
TV Viewing: School day / Weekend			
Low	54.1 / 28.6	54.3 / 33.2	53.9 / 24.8
Medium	30.7 / 54.6	28.4 / 48.1	32.7 / 59.8
High	15.2 / 16.9	17.3 / 18.8	13.4 / 15.4
Computer games: School day / Weekend			
Low	22.9 / 13.6	16.4 / 10.1	28.4 / 16.5
Medium	50.9 / 44.2	45.2 / 32.7	55.5 / 53.5
High	26.2 / 42.2	38.5 / 57.2	16.1 / 29.9
Media access			
Low (1 or no electronic devices)	13.0	14.9	11.4
Average (2-4 electronic devices)	70.8	63.5	76.8
High (5 or 6 electronic devices)	16.2	21.6	11.8
Crime-related safety concerns score	1.1 (0.6)	1.0 (0.6)	1.2 (0.7)
Traffic-related safety concerns score	1.3 (0.5)	1.4 (0.5)	1.3 (0.5)

School day TV viewing categories: Low = < 2 h/d; Medium = 2 h/d; High = ≥ 3 h/d. Weekend TV viewing categories: Low = < 2 h/d; Medium = 2-3 h/d; High = ≥ 4 h/d. School and Weekend Computer categories: Low = None; Medium = < 2 h/d; High = ≥ 2 h/d.

GCSEs, General Certificate for Secondary Education; SES, socioeconomic status; TV, television.

6.4.1 Outdoor Time After School

SES, media access, and crime-related safety concerns were associated with outdoor time after school in the simple models (Table 6.2). These variables remained significant in the mutually adjusted model. In comparison to high SES participants, low SES children were 1.77 times more likely to spend > 1 hour outside after school, and children with access to a low number of electronic devices (0 or 1) were less likely to report a high level of time outdoors after school than those with high access to several electronic devices (5 or 6). No significant difference was found between the average and high media access groups. A one unit increase in the crime-related safety concerns score was associated with 1.51 higher odds of spending > 1 hour outside after school. Sex and time spent on a computer on a

school day were significantly associated with time outdoors after school in the mutually adjusted model. Compared to girls, boys were 1.72 times more likely to spend a high level of time outdoors after school, and children who spent < 2 hours of their time playing on a computer on school days were 1.98 times more likely to spend > 1 hour outside after school than those reporting 2 or more hours of computer use. Although the overall effect of TV viewing on a school day was not statistically significant, those watching TV for < 2 hours/school day displayed lower odds of time outdoors after school than those watching TV for 3 or more hours.

A significant interaction by sex was found for traffic-related safety concerns (p=0.022). A unit increase in the traffic-related safety concerns score was associated with lower odds of spending more time outdoors after school in boys only (OR=0.52, 0.28-0.97; p=0.040). No significant relationship was observed for girls (OR=1.36, 0.84-2.21; p=0.207).

6.4.2 Weekend Outdoor Time

Only age was significant in both the simple and mutually adjusted models for weekend outdoor time (Table 6.3). Older age was associated with higher odds of spending > 2 hours outdoors on a weekend, though significant interactions by sex (p=0.009) and SES (p=0.027), showed that the relationship for age was only significant in girls (OR=2.54, 1.43-4.51; p=0.002) and high SES participants (OR=2.25, 1.34-3.77; p=0.002). Equivalent odds ratios for boys and low SES participants were 0.79 (0.39-1.62; p=0.521) and 0.68 (0.27-1.71; p=0.410), respectively.

6.4.3 Associations with Access to Specific Electronic Media Devices

The odds of spending more time outdoors, according to whether participants had access to specific media devices or not, are shown in Figure 6.1. Only two relationships were statistically significant: in comparison to those who did not have a TV in their bedroom, children who did were 2.03 (1.34-3.07; p=0.001) times more likely to spend > 1 hour outside after school, and children with a non-hand held video game player (e.g., Playstation, Xbox etc.) in their bedroom were 1.79 (1.09-2.93; p=0.022) times more likely to spend this long outdoors after school. No significant associations were found for weekend outdoor time, although the association for use of a hand-held video game player approached significance;

Table 6.2. Odds associated with spending > 1 hour/day outdoors after school: Odds Ratios and 95% CIs

	Model 1		Model 2	
	OR (95% CI)	***p***	**OR (95% CI)**	***p***
Demographics				
Age	0.89 (0.54-1.46)	0.641	0.84 (0.51-1.39)	0.499
Sex (Ref = Girls)	1.37 (0.93-2.03)	0.111	1.72 (1.12-2.65)*	*0.014*
SES (Ref = High education)	1.97 (1.26-3.08)*	*0.003*	1.77 (1.12-2.80)*	*0.015*
Home electronic media environment				
School day TV viewing (Ref = High; ≥ 3 h/d)	1	0.236	1	0.116
Mid (2 h/d)	0.70 (0.38-1.29)		0.58 (0.31-1.09)	
Low (< 2 h/d)	0.62 (0.35-1.08)		0.54 (0.30-0.97)*	
School day computer games (Ref = High; ≥ 2 h/d)	1	0.168	1	*0.030*
Mid (< 2 h/d)	1.57 (0.97-2.54)		1.98 (1.20-3.30)*	
Low (None)	1.24 (0.70-2.19)		1.72 (0.94-3.15)	
Media access (Ref = High; 5-6 devices)	1	*0.013*	1	*0.014*
Average (2-4 devices)	0.83 (0.47-1.44)		0.83 (0.47-1.46)	
Low (0-1 devices)	0.34 (0.15-0.75)*		0.33 (0.15-0.75)*	
Parental safety concerns				
Crime-related	1.47 (1.08-2.01)*	*0.015*	1.51 (1.09-2.10)*	*0.013*
Traffic-related†	0.96 (0.66-1.39)	0.812	0.82 (0.55-1.21)	0.312

Model 1: Simple associations between each independent variable and outdoor time after school, adjusting for covariates (age, sex and SES). Odds ratios for demographic variables (age, sex and SES) are therefore taken from a model in which all three were included simultaneously. Schools were treated as random effects in all models.

Model 2: Mutually adjusted model with all independent variables entered simultaneously, with schools treated as random effects.

Effects of continuous variables are assessed as one unit offsets from the mean.

*p<0.05

†A significant interaction for traffic-related safety concerns*sex (p=0.022) was found; see text for details.

P values taken from Type 3 Tests of Fixed Effects; italic font indicates significant result.

Ref, reference category; SES, socioeconomic status; TV, television.

Table 6.3. Odds associated with spending > 2 hours/day outdoors on a weekend: Odds Ratios and 95% CIs

	Model 1		Model 2	
	OR (95% CI)	***p***	**OR (95% CI)**	***p***
Demographics				
Age†	1.59 (1.02-2.48)*	*0.039*	1.61 (1.01-2.57)*	*0.045*
Sex (Ref = Girls)	1.24 (0.84-1.83)	0.276	1.26 (0.82-1.92)	0.292
SES (Ref = High education)	1.22 (0.79-1.89)	0.359	1.19 (0.76-1.87)	0.454
Home electronic media environment				
Weekend TV viewing (Ref = High; ≥ 4 h/d)	1	0.184	1	0.203
Mid (2-3 h/d)	0.62 (0.35-1.08)		0.63 (0.36-1.11)	
Low (< 2 h/d)	0.59 (0.32-1.08)		0.58 (0.31-1.09)	
Weekend computer games (Ref = High; ≥ 2 h/d)	1	0.309	1	0.297
Mid (< 2 h/d)	0.80 (0.52-1.22)		0.86 (0.55-1.35)	
Low (None)	1.23 (0.65-2.30)		1.40 (0.72-2.71)	
Media access (Ref = High; 5-6 devices)	1	0.957	1	0.953
Mid (2-4 devices)	1.05 (0.60-1.81)		1.09 (0.62-1.90)	
Low (0-1 devices)	1.12 (0.53-2.38)		1.11 (0.51-2.39)	
Parental safety concerns				
Crime-related	1.16 (0.86-1.57)	0.334	1.14 (0.83-1.57)	0.416
Traffic-related	1.02 (0.70-1.49)	0.902	1.01 (0.69-1.49)	0.956

Model 1: Simple associations between each independent variable and weekend outdoor time, adjusting for covariates (age, sex and SES). Odds ratios for demographic variables (age, sex and SES) are therefore taken from a model in which all three were included simultaneously. Schools were treated as random effects in all models.

Model 2: Mutually adjusted model with all independent variables entered simultaneously, with schools treated as random effects.

Effects of continuous variables are assessed as one unit offsets from the mean.

*p<0.05

†A significant interaction for age*sex (p=0.009) and for age*SES (p=0.027) was found; see text for details.

P values taken from Type 3 Tests of Fixed Effects; italic font indicates significant result.

Ref, reference category; SES, socioeconomic status; TV, television.

children with such a device were less likely to spend > 2 hours outdoors on weekend days than those without one (OR=0.62, 0.38-1.01; p=0.056).

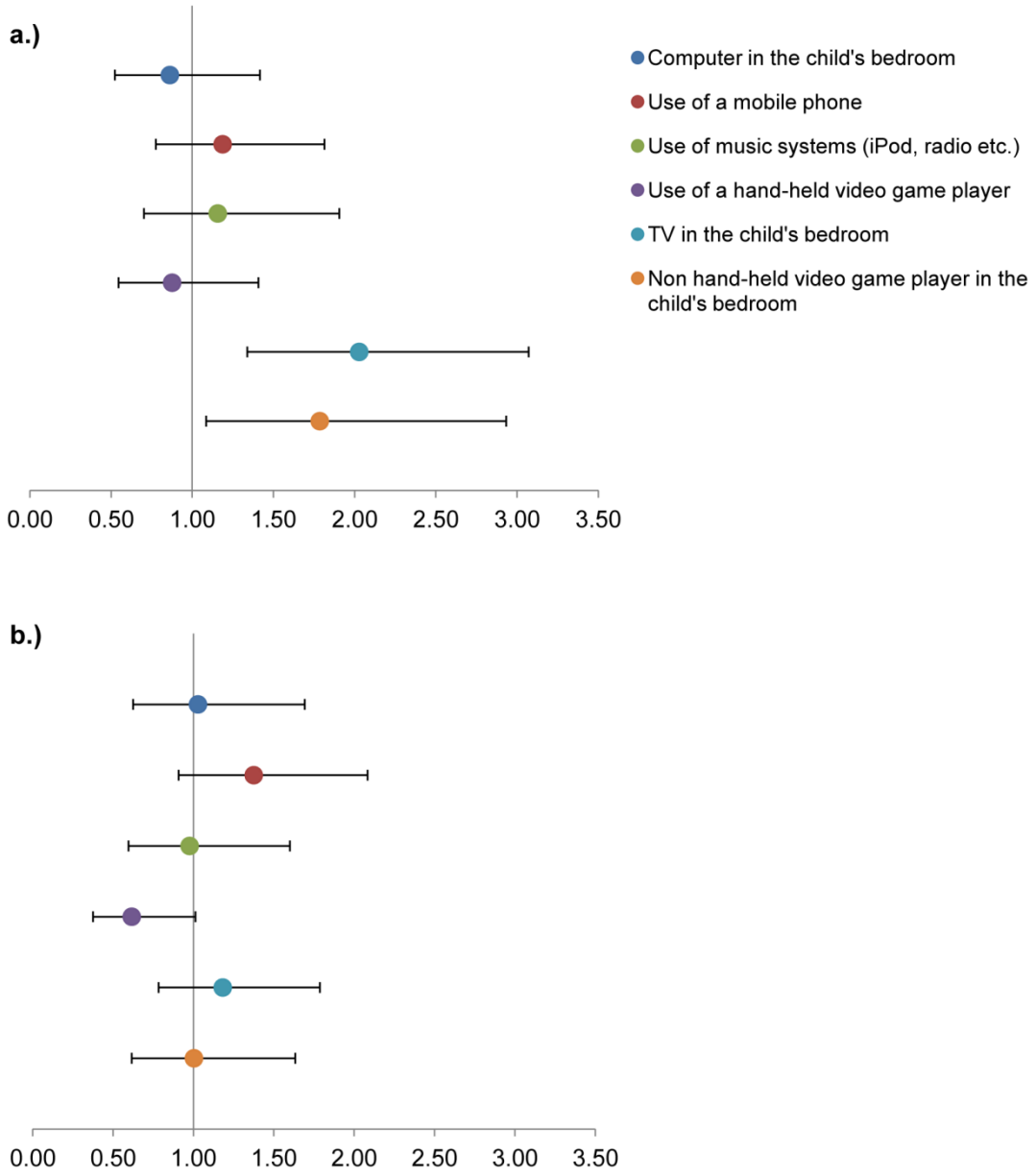

Figure 6.1 Odds associated with spending a.) > 1 hour outside after school; b.) > 2 hours outdoors on a weekend, according to whether children have access to specific electronic media devices or not (reference category = no access), adjusting for age, sex and SES (highest parental education level), with schools treated as random effects.

6.5 Discussion

The aim of this study was to extend previous research on children's PA, by exploring potential correlates of time spent outdoors, a consistent correlate of children's PA,[3] during specific periods when children have more free choice over their behaviour. The results provide new insight into the relationships between parental safety concerns, screen-based behaviours, and time spent outdoors after school and on weekends. Group differences were also found, as well as interactions by sex and SES.

Boys and low SES children were more likely to spend > 1 hour outside after school than girls and high SES participants, respectively. These relationships did not hold for time spent outside on weekends, but older children were more likely to spend > 2 hours outdoors during this time, although this relationship was only significant among girls and high SES participants. These results are interesting as they align with previous research on independent mobility showing that boys,[16,28,39-42] children of a low SES background,[41-44] and older children,[16,41,42,44] tend to be given greater freedom to roam. As such, independent mobility may be an underlying mechanism that was at play in our study, but more research is needed to confirm this, since independent mobility was not assessed here.

In terms of research on time outdoors specifically, our results concur with past work showing that boys tend to spend more time outdoors than girls.[6,23,28,31] As for socioeconomic differences, a negative relationship between parental education and time outdoors was reported among 3-4 year olds in the US,[24] and among children aged 7-12 years in the Netherlands, but no association was found for 4-6 year olds within the same study.[22] No significant difference was reported in another US study on pre-schoolers aged 2-5 years,[23] thus conflicting results have previously been reported. Age differences, other sample characteristics, and variations in the way that time spent outdoors is assessed, could explain these discrepancies. Research on UK children, exploring socioeconomic disparities in time spent outdoors is needed to support our findings.

According to previous research, a weak negative relationship between sedentary behaviour and PA exists,[19,45] yet little is known about the relationship between screen-based behaviours and outdoor time specifically. Our findings suggest that the time spent playing on a computer is more important than the time watching TV, because a negative association was observed for computer use and outdoor time

after school, whereas no overall effect for TV viewing was found. However, there were differences between the 'extreme' groups in that participants who watched a low amount of TV (< 2 hours/day) on school days were less likely to spend > 1 hour outside after school than those watching a high amount of TV (≥ 3 hours/day).

In addition, access to a TV or non hand-held video game player in the bedroom was associated with higher odds of time outdoors after school in comparison to children without these. Similar findings were reported in a study of 7 year old children; the presence of a TV in the bedroom was positively associated with PA.[46] The authors speculated that this may have been a marker of SES, as they also found low SES participants to be more active than their high SES counterparts.[46] Yet, no significant interaction by SES was found for any of the sedentary pursuits explored in this study, so other factors could be at play. For example, children with access to very few electronic media devices or who watch very little TV, may live in households where ST is more carefully monitored and/or highly prohibited. It is therefore possible that other rules and restrictions may be enforced, such as not being allowed to play outdoors unsupervised. Indeed, previous research has shown that greater restrictions on sedentary behaviours are negatively associated with PA.[47,48] Further research is needed to test whether this mechanism is feasible or whether other reasons, such as reverse causality,[47] for these counter-intuitive findings are at play.

Nevertheless, our findings raise questions about the potential efficacy of previous strategies, such as the removal of devices from the bedroom or TV limiting devices,[49,50] that are proposed to increase children's PA levels. However, such proposals are based on results showing that greater access to media devices in the child's bedroom is negatively associated with children's PA and positively with sedentary time,[43,48] which contrasts with our findings. Such differences may simply be due to the fact that we assessed outdoor time specifically, as opposed to overall PA. Alternatively, there may be variations in the way that electronic media devices are reported (i.e., via child versus parent reports),[51] and devices in the child's bedroom may have contrasting effects to those that are portable in nature. As children have access to a number of sedentary screen-based devices,[37] new research exploring the impact of time spent in other screen-based pursuits (e.g., tablet computers and smart phones) is needed as it will be important to know whether they add to, or replace, the use of existing devices already present in the home.

In terms of parental safety perceptions, a significant negative association was evident for traffic-related concerns and time outdoors after school among boys. This contrasts with the results of another UK study, whereby a negative relationship between traffic safety concerns and time spent outside was apparent among girls only.[52] It is unknown why such a relationship was not observed for girls in this study, but it could be because fewer girls spent several hours outside during this time than boys. Furthermore, in contrast to our approach, in their study the authors examined outdoor time across the whole week as well as children's perceptions of safety as opposed to parental perceptions.[52] Again, such discrepancy in design may explain differences when compared to the present work. Nonetheless, it may be that road safety strategies targeting boys' safe play or active transport around the neighbourhood may be needed among those who have parents that restrict their outdoor time. Though, safety measures should be enforced such that they do not compromise on children's ability to partake in unsupervised outdoor play.[8,53]

As for crime-related concerns, the results were less intuitive because higher concerns of this kind were associated with increased odds of time outside after school in this sample. It is possible that parents with more concerns experience these because their children spend more time outdoors, thus they may be more aware of potential dangers.[54] Equally, it may be that such parents do not restrict their child's behaviour despite feeling concerned. They may therefore have effective coping strategies; if so qualitative studies which look to explore these would be useful as they may provide a means for overcoming concerns among parents who do restrict their child's outdoor time. On the other hand, it may be that these children spend more time outdoors in protest to any restrictions placed upon them,[55] though this seems unlikely given the age group being studied. A more plausible explanation is that parents who report greater concerns may simply supervise their children's outdoor play or active travel.[55] This emphasises the importance of taking the whole context into account, by specifying where and with whom such behaviour takes place, as well as the need for longitudinal research given that the direction of this relationship is unknown because of the cross-sectional study design.

6.5.1 Limitations

This study is also limited by the use of self-reported measures to assess all variables included in the analysis. It has been proposed that mixed methods designs, including both objective and subjective measures of outdoor play, and a standardised measurement tool should be employed in future research.[56] However,

a strength of this work is the inclusion of time-specific data for both screen-based pursuits and time spent outdoors, which can help to improve the predictive capacity of the relationships being tested.[57]

It is possible that other factors not studied here may play an important role (e.g., access to facilities, parent support, seasonality etc.) that should also be explored in future. Further, the majority of the sample classified themselves as White British, and data were not collected on children living in rural areas. Consequently, the findings of this study may not generalise to other populations and important differences between ethnic groups or between urban and rural settings could not be assessed. Parental perceptions of the neighbourhood environment are more likely to be influential in this age group, though future studies should explore the impact of both children's and parent's perceptions, as they may have independent and/or interacting effects.[12,52]

6.5.2 Conclusions

In conclusion, our results show that certain groups of children (i.e., girls, high SES children, younger age groups, and those who play on a computer for long periods of time) are at greater risk of spending their free time indoors, which could have important health implications with regards to their development and PA levels. Thus, interventions designed to promote PA among such groups may benefit from increasing their time outdoors during discretionary periods. Some counterintuitive findings were also reported in terms of the electronic media environment and crime-related safety concerns because positive associations with these and time outdoors after school were found. Further research, including longitudinal studies, is needed to test some of the proposed mechanisms that may be at play in order to explain these results.

6.6 References

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Chapter 6 Closing Commentary

Atkin and colleagues[67] recently argued that correlates of PA will not necessarily vary between different groups of children despite some reporting higher PA levels than others (e.g., girls vs. boys). They therefore recommend testing for interactions first as opposed to immediately stratifying results without checking whether any significant differences between groups are present.[67] The results for Chapters 4 and 5 were presented for the total sample and group differences were not explored as we were primarily interested in correlates of PA across the entire sample in order to inform analyses for the final two chapters. However, interactions by sex and SES were explored in this chapter, which provided novel information because the results showed that certain groups (girls and high SES children) had lower odds of time spent outdoors after school than others (boys and low SES children), and age was found to be important for their outdoor time on weekends. In addition, traffic-related safety concerns were negatively associated with time spent outside after school in boys only. This provides more detailed information about how potential correlates can differ according to the group, time and behaviour in question. Future research should also look to explore such relationships in greater depth, by testing for interactions or conducting mediation analyses, as they could provide useful information for future intervention design.

The other results of this paper were interesting as they provided some unexpected findings in relation to crime-related safety concerns, TV viewing and access to electronic media devices as positive relationships between these correlates and time spent outdoors after school were found. In contrast, a negative relationship was observed for computer use specifically as children who played on a computer for < 2 hours on school days displayed higher odds of time outdoors after school than those who played on a computer for longer than this. However, no significant difference was found between the excessive computer gamers and those who reported not spending any time playing computer games at all. These results were fairly similar to those found in Chapter 4, in that a significant relationship was observed for computer use but not TV viewing. We wanted to explore this further, and in more detail, in the final chapter in order to get a better grasp of what might be going on and to assess whether similar relationships were observed in other countries across all 12 ISCOLE sites.

CHAPTER 7

A test of the displacement hypothesis: time, sex, and socioeconomic differences in the relationships between screen-based behaviours and intensity-specific physical activity in a multi-national sample of children.

Chapter 7 Opening Commentary

Throughout all previous chapters ST has been included as a potential correlate. Due to a lack of consistency in the results for this particular variable it was deemed necessary to get a better idea of the relationships at play between screen-based behaviours (i.e., recreational computer use and TV viewing) and different PA outcomes (i.e., overall and time-specific LPA and MVPA). LPA was assessed in addition to MVPA seen as computer use displayed a negative relationship with this in Chapter 4. Consistent with the previous two chapters, PA of this kind during discretionary periods (after school/weekend) was assessed, and overall measures of LPA/MVPA across the week were also included.

It was deemed important to look at the relationships by sex and SES, given that there is potential for the displacement hypothesis to differ according to boys and girls and children from different socioeconomic backgrounds. However, due to a potential lack of power when stratifying by sex and SES in the UK-specific sample, this chapter was extended to include data from all 12 ISCOLE sites. The UK-specific results were still explored and have been presented in the post-commentary text of this Chapter, and the results helped to see whether similar relationships were evident in other developed countries.

Statement of Authorship

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7.1 Abstract

Background: Increasingly, children have access to an array of screen-based entertainment, which may compete for time in PA. The purpose of this study was to explore relationships between screen-based pursuits and PA according to sex and SES, in children from countries varying in levels of development and SES.

Methods: Complete data on the pertinent study variables were collected from 9-11 year olds (n=6237) from study sites in 12 countries. PA was objectively measured using accelerometers and participants reported how much time they spent watching TV or playing on a computer on school and weekend days. Linear mixed models were computed to analyse the relationships between each sedentary behaviour and PA outcome (after school, weekend and overall LPA and MVPA), stratified by sex and SES (highest parental education). Interactions by site were included and cross-country comparisons were examined.

Results: Recreational computer use was negatively associated with LPA and MVPA among boys during discretionary periods only (i.e., after school and over the weekend), whereas a negative relationship was observed for all LPA outcomes among girls. A negative association was observed between TV viewing and after school/weekend LPA and MVPA in girls. In contrast, boys who reported watching TV for long periods recorded higher overall LPA and MVPA. No associations were found between TV viewing and PA stratified by SES. Only one significant negative relationship was found among low SES children for computer use and LPA after school. High SES participants who spent ≥ 2 hours/day using a computer recorded lower LPA and MVPA across most time periods than those who did so for less time. However, this association varied by site and was more evident among children from high income countries. Children who met ST guidelines had higher odds of achieving 60 minutes of MVPA per day, though this also varied by site.

Conclusions: Screen-based pursuits may displace children's PA, though this may only be the case among specific groups during particular times. Recreational computer use generally appeared to have more of an effect than TV viewing, especially among high SES children within high income countries.

7.2 Background

Marked increases in the prevalence of childhood obesity have been observed over the past three decades in both developed and developing countries.[1] Although prevalence estimates appear to have plateaued in developed countries, a decline in

childhood obesity levels is yet to be observed and it is likely that figures will continue to rise in developing countries.[1] This presents a severe public health challenge given its associated health risks.[2,3]

Causes of childhood obesity are complex and many factors are attributed to increases in weight gain including changes in lifestyle behaviours such as a lack of PA, energy-dense dietary patterns, and an increase in time spent in sedentary behaviours.[4] In terms of sedentary behaviour, technological developments and increased access to multiple electronic devices may be putting children at risk of ill-health, especially given that prolonged periods of time are spent inactive (i.e., sitting), while using such appliances.[5,6]

TV viewing in particular has been positively associated with obesity,[7,8] and two key mechanisms behind this association have been proposed. First, that children tend to consume more energy-dense foods while watching TV.[7,9] Second, that TV viewing displaces PA.[10] However, there has been a lack of support for the latter (i.e., the displacement hypothesis) in previous research. According to two meta-analyses, a significant negative relationship exists between TV viewing/ST and PA but effect sizes are small, thus the association is weak.[10,11] There also appeared to be no difference in the results when relationships during specific times of the week were assessed (i.e., after school and weekends) in the most recent meta-analysis.[11] However, previous research tends to be limited by the use of overall PA as an outcome measure, as opposed to time-specific PA measured over the same time-segment as the screen-based behaviour in question.[11] Thus, important associations may have been missed by this lack of specificity.

Further, there are likely gender and socioeconomic differences given that boys,[12-17] and children classified as having a low SES[17-22] tend to spend more time engaged in screen-based behaviours. The pattern of association between ST and PA may also differ between countries that vary in terms of their economic development. For example, contrasting associations were reported for the SES-obesity relationship in countries that differed in terms of their human development index in a recent study.[23] Positive associations between markers of body weight and SES occurred in countries with lower levels of development while negative associations were observed in countries with higher levels of development.[23]

The purpose of this study was to explore the displacement hypothesis using a more refined approach, in a large sample of children from twelve countries that varied

widely in terms of their socioeconomic, cultural, climatic and geographic setting.[24] Associations between screen-based behaviours (TV viewing and recreational computer use) and intensity-specific PA (LPA and MVPA) across the week and during particular times (after school and weekend), were assessed by sex and SES. Country level differences were examined throughout as data were collected via a robust standardised protocol, therefore permitting cross-country comparisons. A secondary aim was to assess the relationship between overall ST (taking both TV viewing and computer use into account) and the odds associated with meeting international guidelines for MVPA,[25] by site.

7.3 Methods

7.3.1 The ISCOLE Study

Study sites from twelve countries, spanning five major geographic regions of the world (Africa, Europe, the Americas, South East Asia, and the Western Pacific) participated in the ISCOLE study.[24] Countries were selected for their differences in a number of socioeconomic, cultural, and climatic indicators.[24] Participating countries classified as high income, as per the World Bank Classification,[26] include Australia (Adelaide), Canada (Ottawa), Finland (Helsinki, Espoo and Vantaa), Portugal (Porto), the UK (Bath and North East Somerset), and the US (Baton Rouge). Upper-middle income countries include Brazil (São Paulo), China (Tianjin), Colombia (Bogotá) and South Africa (Cape Town). Lower-middle income countries include India (Bangalore), and Kenya (Nairobi).[‡] A detailed account of the ISCOLE design and methods has been published elsewhere.[24]

7.3.2 Study Design and Participant Characteristics

A rigorous protocol was employed across all study sites, in that ISCOLE staff members were trained prior to data collection, which included sessions on how to perform measurements in a standardised fashion and completion of numerous certification requirements.[24] Quality control procedures were also enforced and managed by the Coordinating Center in Baton Rouge, US, to ensure consistency and accuracy within and between sites.[24] A cross-sectional study design was employed and data were collected between September 2011 and December 2013. Children aged 9-11 years old were targeted across schools stratified by markers of

[‡]Note that at the time of data collection, Kenya was classified as a low income country.[24]

SES in order to maximise the variability within each site.[24] Informed parental consent and child assent were obtained prior to data collection and ethic approval was obtained from each site. Ethic approval for the overall ISCOLE study was granted by the Pennington Biomedical Research Center Institutional Review Board.[24]

7.3.3 Measures

7.3.3.1. Outcome Variables: Objectively Assessed Physical Activity

Participants were provided with an ActiGraph GT3X+ accelerometer (ActiGraph LLC, Pensacola, FL, USA) to wear at their waist using an elastic belt. They were asked to wear the device for 7 days, and instructed not to take it off except for showering/bathing and water-based activities. A 24-hour protocol was employed in order to increase compliance and to enable measurement of PA performed during specific times.[27] To be included in the analysis, participants needed to have a valid accelerometry file which included data with at least 10 hours of wear time per day for a minimum of 4 days, including at least one weekend day.[27] Consecutive zero counts for periods of 20 minutes or more were classified as non-wear.[28] Validated cut-points were used to quantify both MVPA (≥ 574 counts/15 seconds) and LPA (26-573 counts/15 seconds).[29,30] The mean duration of LPA and MVPA per day across the entire week and per weekend day was calculated to assess overall and weekend PA levels. The mean time spent in LPA and MVPA after school was also calculated, defined as the end of the school day (based on school finish times for each participating school) until the onset of sleep, computed using a previously published automated algorithm.[31] Children were also grouped according to whether they achieved a mean of 60 minutes MVPA per day or not, in line with international PA guidelines, as recommended by WHO,[25] in order to assess the secondary aim of the paper.

7.3.3.2. Independent Variables: Screen-based Behaviours

Data were also collected using questionnaires, and participants were asked four questions, from the Youth Risk Behaviour Surveillance System,[32] regarding the number of hours they spent both watching TV and playing on a computer, on school and weekend days in the last week. Participants could choose from 7 options coded as follows: 0 = 'I did not watch TV'/'I did not play video/computer games or use a computer other than for school work'; 0.5 = '< 1 hour'; 1 = '1 hour'; 2 = '2 hours'; 3 = '3 hours'; 4 = '4 hours' 5 = '5 or more hours'. Using these data, four independent

variables were created (school day TV viewing, weekend TV viewing, school day computer games, and weekend computer games), by categorising participants into three groups to assess the time spent in each behaviour during both time periods. The categories used for each variable are described as follows:

- School day TV viewing: < 2 hours, 2-3 hours, ≥ 3 hours per school day.
- Weekend TV viewing: < 2 hours, 2-4 hours, ≥ 4 hours per weekend day.
- School day/weekend computer games: None, < 2 hours, ≥ 2 hours per school/weekend day.

These categories were chosen based on a frequency analysis of the groupings, and akin to previous research using similar cut-points (e.g.,[15,33]). In order to assess overall levels of TV viewing and computer games, a weighted mean daily score for each was calculated and both variables were then categorised, as follows:

- Overall TV viewing = (school day TV viewing*5 + weekend TV viewing*2)/7. Categories created: < 2 hours, 2-3 hours, ≥ 3 hours per day.
- Overall computer games = (school day computer games*5 + weekend computer games*2)/7. Categories created: None, < 2 hours, ≥ 2 hours per day.

For the secondary aim, children's overall ST was computed by summing their TV and computer scores using the following formula: (school day TV*5 + school day computer*5 + weekend TV*2 + weekend computer*2)/7. This variable was then dichotomised according to whether participants met ST guidelines or not (i.e., ≤ 2 hours vs. > 2 hours ST per day), which have been adopted in Australia,[34] Canada,[35] and the US.[36]

7.3.3.3. Covariates - Biological/Demographic Variables

Anthropometric measurements were collected during a visit to the school, whereby children's standing height and weight were measured using a Seca 213 portable stadiometer (Seca Corporation, Hamburg, Germany), and a portable Tanita SC-240 Body Composition Analyser (TANITA Corporation, Tokyo, Japan). Two measurements were taken and the average height and weight was calculated; a third measurement was performed if the first two measurements were > 0.5 cm or > 0.5 kg apart. BMI was calculated (weight (kg)/height $(m)^2$), and z-scores were computed using the WHO growth curves.[37]

Parents/guardians were asked to provide their child's sex and date of birth, from which their decimal age was calculated at the time of data collection. Parents/guardians were also asked about their highest level of education attained, which was used as an indicator of SES. Participants were dichotomised into low and high SES groups based on parents who reported achieving a high school qualification/equivalent or less, and those with some college and/or University degree.

7.3.4 Statistical Analysis

All analyses were conducted in SAS Studio 3.5 (SAS Institute Inc., Cary, NC, USA, 2012-2016). A target sample size of 500 children across a minimum of 20 schools within each site was set, in order to achieve a sample of at least 6000 participants across all sites, which was deemed to provide excellent power.[24] Participants were excluded if they had missing or invalid data for any measures included in the analysis. Descriptive statistics were computed first and comparisons between included and excluded participants were tested using independent samples t-tests and chi-square tests. Null models were produced for each outcome variable to assess the proportion of variability in PA at all levels (individual, school and site) using the ICCs.

For the main analysis, linear mixed models were computed to explore the relationships between each screen-based behaviour and all outcome variables stratified by sex and SES, using the MIXED procedure and the Kenward and Roger approximation for degrees of freedom.[38] Associations between the relevant independent and dependent variables were modelled according to the specific reference period in question, in order to improve the predictive capability of relationships (i.e., the associations between weekend day TV viewing/computer games and weekend PA etc. were assessed).[11,39] Age, sex, SES, BMI z-score, and registered accelerometer wear time were included as covariates, with sites treated as fixed effects, and schools within sites viewed as random effects. A site*variable interaction was also included in all models, and where a significant interaction was found, the results by site were explored using the DIFF option in the LSMEANS statement. Results are presented as least squares means and p values are taken from Type 3 Tests of Fixed Effects. Bonferroni adjusted p values were obtained where multiple comparisons were made. For the secondary purpose of this paper, a generalised linear mixed model was produced to obtain the odds associated with

meeting the MVPA guidelines according to whether children met overall ST guidelines or not, by site, using the SLICEDIFF option in the GLIMMIX procedure.

7.4 Results

From a total of 7372 consenting participants considered eligible to participate,[40] 1135 had missing/invalid data for at least one variable, leaving an analytic sample of 6237 children (45.6% were boys and 45.2% were classified as having a low SES). Excluded participants were more likely to be male, older, and from a low SES background. They also had a higher BMI z-score, spent longer in screen-based behaviours and were less likely to meet the MVPA guidelines. However, they also had a higher mean time spent in MVPA after school. No other significant differences were observed between those included or excluded from the analytic sample. The ICCs revealed that the largest amount of variability in PA occurred at the individual-level (45%-84%), followed by the site- (7%-31%) and school-levels (6%-24%).

Descriptive characteristics are provided in Table 7.1. The mean age of participants was 10.4 years, and fewer than half of participants met PA (44.4%) and ST (45.4%) guidelines. Boys and low SES participants recorded higher mean minutes of LPA and MVPA than girls and high SES children, respectively. China (15.9%) and India (24.9%) had the lowest proportion of children meeting MVPA guidelines and the highest proportion meeting ST guidelines (i.e., 65.9% and 69.1%, respectively). Finnish children had the highest proportion meeting MVPA guidelines (63.8%), while Brazilian children had the lowest proportion meeting ST guidelines (27.2%).

Table 7.1 Descriptive characteristics of the analytic sample, by sex, SES and site

	n	Age (years)	Sex (% boys)	Mean BMI z-score (SD)	SES (% high education)*	LPA (min/day)	MVPA (min/day)	% meeting MVPA guidelines†	% meeting ST guidelines‡
All Sites									
Total sample	6237	10.4 (0.6)	45.6	0.5 (1.3)	57.2	315.0 (52.6)	60.3 (24.8)	44.4	45.4
Boys	2841	10.4 (0.6)	-	0.5 (1.3)	57.5	319.6 (51.5)	69.8 (25.8)	61.2	38.8
Girls	3396	10.4 (0.6)	-	0.4 (1.2)	57.0	311.1 (53.3)	52.3 (20.9)	30.4	51.0
Low SES	2669	10.4 (0.6)	45.2	0.5 (1.3)	-	318.7 (53.2)	63.8 (26.5)	49.7	41.2
High SES	3568	10.4 (0.6)	45.8	0.4 (1.2)	-	312.2 (52.1)	57.7 (23.1)	40.4	48.6
By site									
Australia (Adelaide)	478	10.7 (0.4)	46.0	0.6 (1.1)	79.3	310.1 (47.8)	65.2 (23.1)	55.2	41.6
Brazil (São Paulo)	448	10.5 (0.5)	48.9	0.9 (1.4)	40.9	338.0 (53.1)	59.4 (26.2)	44.4	27.2
Canada (Ottawa)	517	10.5 (0.4)	41.2	0.4 (1.2)	91.1	304.7 (44.9)	58.6 (19.4)	43.3	54.4
China (Tianjin)	496	9.9 (0.5)	52.0	0.7 (1.5)	49.4	293.5 (53.5)	45.2 (15.9)	15.9	65.9
Colombia (Bogotá)	856	10.5 (0.6)	49.3	0.2 (1.0)	34.0	333.0 (49.4)	68.1 (24.8)	59.5	34.1
Finland (Helsinki, Espoo & Vantaa)	470	10.5 (0.4)	46.4	0.3 (1.1)	72.3	293.4 (43.7)	70.8 (26.2)	63.8	42.3
India (Bangalore)	546	10.4 (0.5)	45.6	0.2 (1.4)	83.2	340.1 (50.5)	48.7 (20.8)	24.9	69.1
Kenya (Nairobi)	500	10.2 (0.7)	46.4	0.01 (1.2)	63.2	329.9 (51.8)	71.6 (31.4)	57.2	47.6
Portugal (Porto)	620	10.4 (0.3)	43.4	0.9 (1.1)	20.8	301.8 (50.0)	56.0 (21.8)	35.8	51.3
South Africa (Cape Town)	401	10.2 (0.7)	39.7	0.3 (1.3)	26.4	321.5 (53.2)	63.5 (25.4)	49.6	38.2
UK (Bath & North East Somerset)	430	10.9 (0.4)	43.5	0.4 (1.1)	71.6	286.1 (45.5)	64.2 (22.4)	52.6	32.1
US (Baton Rouge)	475	9.9 (0.6)	41.1	0.7 (1.3)	72.8	313.7 (51.0)	49.9 (18.8)	26.3	39.8

*Parents who reported some college education, and/or a University degree
†The % of children achieving a mean of at least 60 minutes MVPA per day[25]
‡The % of participants reporting ≤ 2 hours of screen time per day[34-36]
BMI, body mass index; LPA, light intensity physical activity; MVPA, moderate-to-vigorous intensity physical activity; SES, socioeconomic status; ST, screen time

7.4.1 Associations by Sex

7.4.1.1. TV Viewing

The associations between screen-based behaviours and PA by sex are presented in Table 7.2. A significant relationship was observed between overall TV viewing and overall LPA/MVPA for boys; those who reported watching the most TV (≥ 3 hours/day) recorded significantly more LPA than those watching TV for less time. The same was found for MVPA, although a significant difference was found between the high (≥ 3 hours/day) and medium (2-3 hours/day) TV groups only. In girls a significant negative relationship was found for after school and weekend LPA/MVPA, although the association for after school MVPA only approached significance ($p=0.056$).

7.4.1.2. Computer Games

For computer games, a negative relationship was found for boys' after school and weekend LPA and MVPA; those who reported not playing any computer games recorded the highest PA levels. However, for both weekend LPA and after school MVPA a significant site*computer interaction was found. The relationship for weekend LPA was only significant among Australian participants ($p<0.001$), and the largest difference was between the 'high' and 'none' computer groups, with the latter recording an average of 59 more minutes of LPA on a weekend ($p<0.001$). In terms of after school MVPA, significant associations were found for Colombia, UK, and Finland. The largest differences were observed in the UK and Finland. UK children who played no computer games did 8-9 more minutes of MVPA after school than children in the other groups ($p<0.02$), while Finnish children in the 'medium' group recorded 8 more minutes of MVPA after school than the 'high' group ($p<0.001$).

Time spent playing computer games was negatively associated with LPA only among girls, and a significant interaction by site was found for the after school period. Significant relationships were found for Australia, Portugal and Finland; children in each of these sites displayed fewer minutes of LPA as time playing computer games increased. The largest differences were observed in Finland; excessive computer gamers recorded 18-19 fewer minutes of LPA after school than the other two groups ($p<0.0001$).

Table 7.2. Relationships between screen-based behaviours and physical activity outcomes, by sex: least squares means and 95% CIs

		TV viewing				Computer games			
		Low	**Medium**	**High**	***p***	**None**	**Medium**	**High**	***p***
Boys	**LPA**								
	Overall	319.2 (316.3-322.2)	317.8 (313.6-322.1)	326.0 (321.1-330.9)[a,b]	**.015**	326.6 (319.8-333.4)	319.9 (317.0-322.9)	318.2 (314.0-322.4)	.086
	After school	147.2 (145.6-148.9)	147.8 (145.3-150.2)	149.1 (146.5-151.7)	.409	150.2 (148.1-152.3)	147.7 (145.8-149.5)	145.4 (143.1-147.6)[a]	**.003**
	Weekend	308.3 (303.9-312.7)	309.4 (305.5-313.4)	313.1 (308.1-318.1)	.287	317.9 (310.9-324.9)	312.7 (308.4-317.0)	305.5 (301.8-309.2)[a,b]	**.001**
	MVPA								
	Overall	71.5 (69.7-73.3)	69.0 (66.6-71.4)	72.9 (70.2-75.5)[b]	**.021**	72.8 (69.3-76.4)	71.4 (69.5-73.2)	70.0 (67.7-72.4)	.277
	After school	35.3 (34.2-36.3)	33.6 (32.0-35.1)	35.4 (33.7-37.0)	.088	36.2 (34.8-37.5)	34.4 (33.1-35.6)[c]	34.5 (33.1-36.0)	**.034**
	Weekend	66.7 (63.9-69.5)	65.6 (63.0-68.2)	67.1 (64.0-70.1)	.627	72.1 (68.0-76.3)	67.3 (64.5-70.1)	63.6 (61.2-66.1)[a,b]	**<.0001**
Girls	**LPA**								
	Overall	312.6 (309.7-315.5)	311.2 (307.0-315.4)	311.3 (306.2-316.4)	.731	314.9 (310.8-319.0)	312.8 (309.9-315.8)	306.9 (301.2-312.6)[a]	**.048**
	After school	151.3 (149.7-152.8)	150.0 (147.7-152.3)	147.4 (144.8-150.1)[a]	**.019**	152.1 (150.3-153.8)	151.0 (149.2-152.7)	146.4 (143.4-149.3)[a,b]	**.002**
	Weekend	310.6 (306.8-314.5)	304.3 (300.7-307.9)[c]	302.0 (296.7-307.2)[a]	**.004**	312.7 (308.3-317.2)	306.2 (302.5-309.9)[c]	300.8 (296.6-305.1)[a]	**<.001**
	MVPA								
	Overall	53.3 (51.7-54.9)	52.1 (50.1-54.1)	51.4 (49.1-53.6)	.068	53.8 (51.8-55.7)	52.9 (51.3-54.5)	51.7 (49.2-54.1)	.228
	After school	27.4 (26.5-28.4)	26.9 (25.7-28.2)	25.9 (24.5-27.3)	.056	27.6 (26.5-28.6)	27.1 (26.1-28.2)	26.2 (24.7-27.7)	.171
	Weekend	51.1 (49.1-53.1)	47.8 (45.9-49.7)[c]	46.3 (43.8-48.9)[a]	**<.001**	49.9 (47.7-52.1)	48.4 (46.4-50.3)	47.4 (45.3-49.6)	.132

Results are presented as least squares means, showing the relationships between school day TV/computer and after school physical activity; weekend TV/computer and weekend physical activity; overall TV/computer and overall physical activity. All models are adjusted for age, SES (highest parental education level), BMI z-score, accelerometer wear time and a site*TV/computer interaction. Schools within sites were viewed as having random effects, and site was included as a fixed effect.

Overall and School day TV viewing categories: Low = < 2 h/d; Medium = 2-3 h/d; High = ≥ 3 h/d; weekend TV viewing categories: Low = < 2 h/d; Medium = 2-4 h/d; High = ≥ 4 h/d; Computer games categories: None = 0 h/d; Medium = < 2 h/d; High = ≥ 2 h/d.

Bold font indicates significant relationship (p<0.05); p values taken from type 3 tests of fixed effects.

[a] = Significant difference between 'high' and 'none'/'low' groups for computer/TV; [b] = Significant difference between 'high' versus 'medium' groups; [c] = significant difference between 'medium' vs. 'none'/'low' groups for computer/TV. All taken from Bonferroni adjusted p values.

BMI, body mass index; LPA, light intensity physical activity; MVPA, moderate-to-vigorous intensity physical activity; SES, socioeconomic status; TV, television.

7.4.2 Associations by SES

No significant relationships were found between PA and TV viewing when stratified by SES (Table 7.3). In contrast, significant relationships were observed between computer games and PA outcomes according to SES. Low SES participants who reported not playing any computer games recorded significantly more after school LPA than those who did. No other significant associations were observed for low SES children. For high SES participants, a significant negative relationship was observed between recreational computer use and LPA/MVPA, for five of the six PA time periods. The relationship for after school MVPA was not significant (p=0.062)

A significant interaction by site was found for all associations between computer games and PA within high SES children. A significant negative relationship was found among the Finnish sample for all outcomes. With the exception of Portugal, all other high income countries (Australia, Canada, UK, and US) had significant negative relationships between computer use and the PA outcomes. Mixed findings were observed for upper-/lower-middle income countries. For example, negative associations were found for Brazil (LPA only), and South Africa (weekend PA only), while children in the 'medium' group from Colombia recorded the least MVPA, whereas China, India and Kenya showed null or positive associations.

To explore this further, we pooled together the high income countries and did the same for the upper-/lower-middle income countries to create two groups, hereafter termed as high (HICs) and low (LICs) income countries, respectively. A significant three-way interaction for country income level*computer games*SES for overall MVPA was found, which has been presented in Figure 7.1. A significant negative effect of computer games was found for high SES participants within HICs (p<0.0001).

Table 7.3. Relationships between screen-based behaviours and physical activity outcomes, by SES: least squares means and 95% CIs

		TV viewing				Computer games			
		Low	**Medium**	**High**	***p***	**None**	**Medium**	**High**	***p***
Low SES	**LPA**								
	Overall	320.0 (316.2-323.8)	318.6 (313.0-324.1)	317.4 (310.0-324.9)	.758	322.0 (312.6-331.5)	320.2 (316.4-323.9)	315.8 (310.0-321.7)	.319
	After school	157.3 (155.1-159.4)	155.2 (152.1-158.3)	152.7 (148.4-156.9)	.100	159.9 (157.2-162.6)	155.3 (152.8-157.7)[c]	153.0 (149.8-156.3)[a]	**.001**
	Weekend	312.4 (306.7-318.1)	312.1 (307.2-317.1)	314.9 (308.3-321.6)	.753	315.9 (307.7-324.0)	313.8 (308.4-319.3)	308.3 (303.2-313.5)	.151
	MVPA								
	Overall	64.0 (62.0-66.0)	60.9 (58.2-63.6)	62.4 (58.9-65.9)	.069	60.2 (55.7-64.7)	63.1 (61.1-65.0)	62.1 (59.2-64.9)	.392
	After school	33.1 (31.8-34.4)	31.6 (29.8-33.4)	32.0 (29.7-34.4)	.245	32.8 (31.2-34.4)	31.8 (30.4-33.3)	32.2 (30.3-34.1)	.582
	Weekend	61.6 (58.4-64.8)	58.0 (55.2-60.8)	58.5 (54.9-62.1)	.108	57.5 (53.1-61.9)	60.0 (57.0-63.0)	56.7 (53.8-59.6)	.158
High SES	**LPA**								
	Overall	310.9 (308.0-313.8)	311.2 (307.0-315.4)	316.2 (310.9-321.6)	.153	317.9 (313.2-322.6)	311.3 (308.4-314.1)[c]	308.8 (303.6-314.1)[a]	**.009**
	After school	142.1 (140.6-143.6)	142.9 (140.6-145.1)	142.5 (139.8-145.1)	.821	144.3 (142.6-146.0)	142.1 (140.5-143.8)	139.4 (136.8-142.1)[a]	**.003**
	Weekend	305.0 (300.9-309.0)	299.7 (296.0-303.4)	300.4 (295.4-305.5)	.091	313.2 (308.0-318.3)	303.5 (299.7-307.3)[c]	296.8 (292.9-300.7)[a,b]	**<.0001**
	MVPA								
	Overall	59.0 (57.5-60.5)	57.1 (55.1-59.1)	59.8 (57.4-62.3)	.064	61.1 (58.9-63.3)	58.5 (57.0-60.0)[c]	58.6 (56.2-61.0)	**.034**
	After school	28.4 (27.4-29.3)	27.6 (26.4-28.9)	27.9 (26.5-29.4)	.497	29.1 (28.1-30.1)	28.0 (27.0-29.0)	27.6 (26.2-29.1)	.062
	Weekend	55.2 (53.0-57.4)	53.0 (51.0-55.1)	53.9 (51.4-56.5)	.191	58.1 (55.4-60.7)	53.6 (51.6-55.7)[c]	52.4 (50.3-54.5)[a]	**.001**

Results are presented as least squares means, showing the relationships between school day TV/computer and after school physical activity; weekend TV/computer and weekend physical activity; overall TV/computer and overall physical activity. All models are adjusted for age, sex, BMI z-score, accelerometer wear time and a site*TV/computer interaction. Schools within sites were viewed as having random effects, and site was included as a fixed effect.

Overall and School day TV viewing categories: Low = < 2 h/d; Medium = 2-3 h/d; High = ≥ 3 h/d; weekend TV viewing categories: Low = < 2 h/d; Medium = 2-4 h/d; High = ≥ 4 h/d; Computer games categories: None = 0 h/d; Medium = < 2 h/d; High = ≥ 2 h/d.

Bold font indicates significant relationship ($p<0.05$); p values taken from type 3 tests of fixed effects.

[a] = Significant difference between 'high' and 'none'/'low' groups for computer/TV; [b] = Significant difference between 'high' versus 'medium' groups; [c] = significant difference between 'medium' vs. 'none'/'low' groups for computer/TV. All taken from Bonferroni adjusted p values.

BMI, body mass index; LPA, light intensity physical activity; MVPA, moderate-to-vigorous intensity physical activity; SES, socioeconomic status; TV, television.

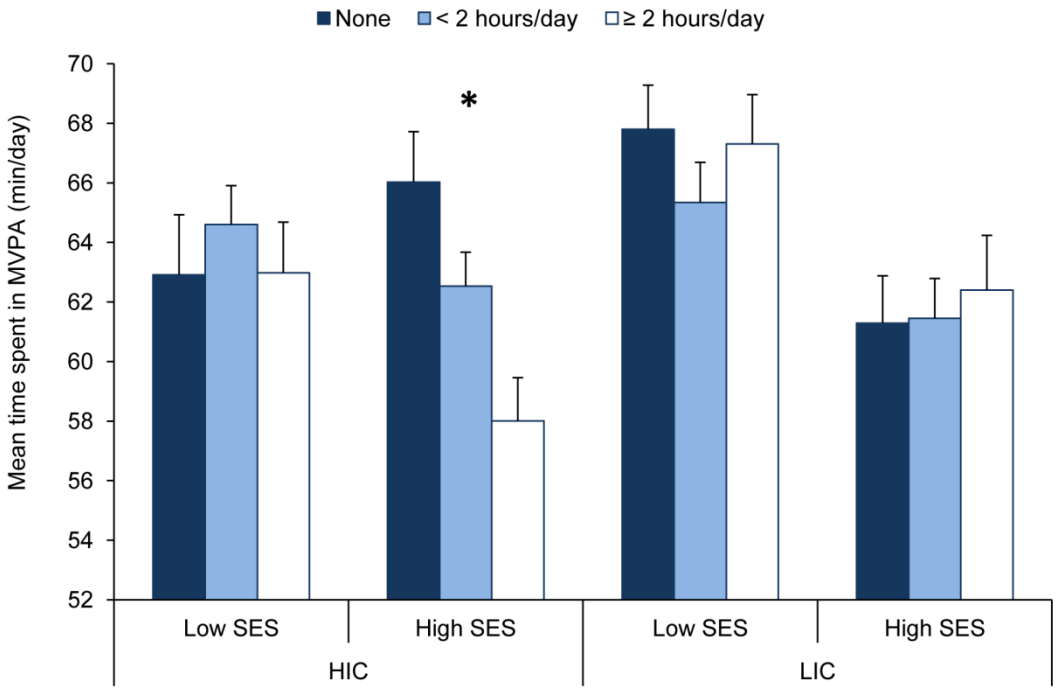

Figure 7.1 Associations between time spent on computer games and accelerometer-derived MVPA, by SES for low (LIC) and high (HIC) income countries.
Error bars represent standard errors. * = significant linear trend (p<0.0001).

7.4.3 Odds Associated with Meeting the MVPA Guidelines

Children who met the ST guidelines (i.e., those who engaged in screen-based behaviour for no more than 2 hours/day) were 1.18 (95% CI: 1.04-1.34, p=0.013) times (i.e., approximately 20%) more likely to achieve at least 60 minutes of MVPA per day (see Figure 7.2). However, this relationship differed by site. Ten of the 12 sites displayed a positive association but this relationship was only significant among Canadian (OR: 1.73, 95% CI: 1.16-2.59, p=0.007), Finnish (OR: 1.91, 95% CI: 1.25-2.94, p=0.003), and South African (OR: 1.69, 95% CI: 1.05-2.72, p=0.030) children. In contrast, children who met the ST guidelines from the US and China were less likely to meet the MVPA guidelines, though this was only significant for the Chinese sample (OR: 0.44, 95% CI: 0.26-0.75, p=0.002).

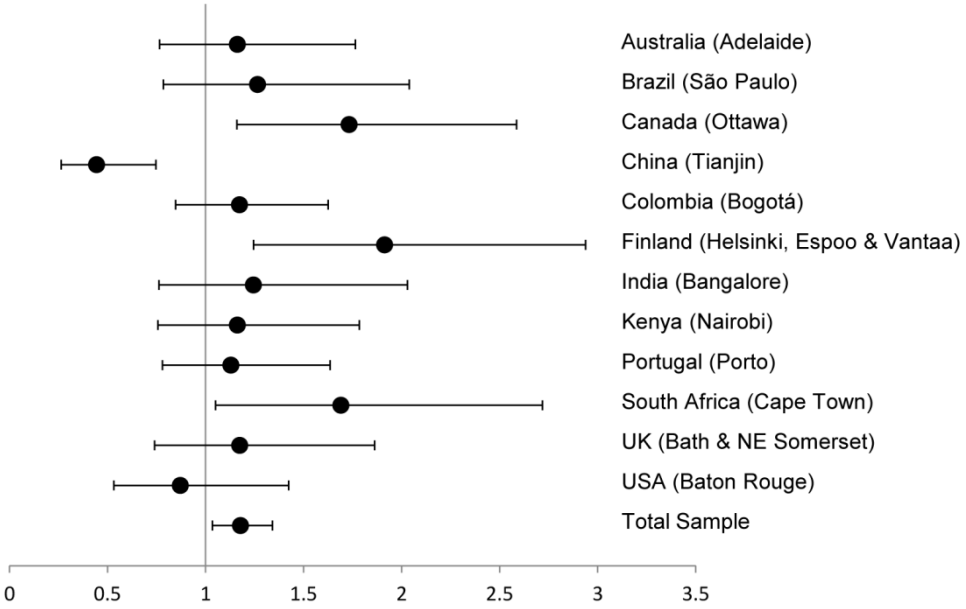

Figure 7.2 Odds associated with meeting the PA guidelines (a mean of 60 minutes MVPA per day) according to level of screen time (≤ 2 hours versus > 2 hours per day) for the total sample and by site, adjusting for covariates (age, sex, SES, BMI z-score, accelerometer wear time), and schools within sites treated as random effects.

7.5 Discussion

The aim of this study was to examine the PA and ST displacement hypothesis according to children's sex and SES. Specifically, we advanced past work by assessing relationships between time spent in screen-based behaviours and intensity-specific PA objectively measured across the week and during discretionary periods in children from countries differing vastly in human and social development. Results of the study provide some support for the displacement hypothesis, especially in terms of recreational computer use as opposed to TV viewing. However, mixed results were found according to the group, PA intensity and time period in question and differences between countries were observed. These factors should therefore be taken into account in future work.

TV viewing is a highly prevalent behaviour during both the after school and weekend periods.[41,42] It would therefore be expected that this behaviour is more likely to displace PA during these times. Yet, TV viewing was negatively associated with both LPA and MVPA after school and over the weekend in girls only. This concurs with the results of a study on Greek-Cypriot children because girls who

watched TV for ≤ 2 hours/day were more likely to be considered active than those watching TV for longer and this relationship did not exist in boys.[43] In our study, boys who reported watching the most TV across the week had higher overall levels of both LPA and MVPA, which is consistent with other research showing that boys can both be highly active and engage in high levels of sedentary behaviour.[44-46] However, the mean differences in PA between groups in the present work were generally small, and no associations were found when stratified by SES. Thus, our findings support the argument that TV viewing is a weak predictor of PA,[7,11] though it may be worth targeting this behaviour among girls as part of a wider intervention strategy to promote their PA during discretionary periods.

Although a TV has been cited as the most commonly reported device present in households across 17 high, middle and low income countries,[47] reported hours spent watching TV actually declined between 2002 and 2010 across 30 countries that took part in the HBSC study.[42] In contrast, computer use and overall ST increased significantly over this period,[42] and children in developed countries, such as the UK, are turning to other media formats including YouTube.[48] Such trends emphasise the need for further research exploring the impact of other screen-based behaviours on PA, particularly given that time spent playing computer games was negatively and significantly associated with PA in all groups for at least one of the measured outcomes in the current study.

Boys who spent prolonged periods of time playing computer games did less LPA and MVPA during their free time, and the largest differences were observed for weekend days and between the two extreme groups. Some differences by site were found; most notably, boys in Australia who reported ≥ 2 hours of computer games on weekend days recorded an hour less of LPA on average than those who did not play any. As for girls, significant negative associations were found between computer game play and all LPA outcomes. These findings may indicate a lack of breaks when engaging in such behaviour, supporting the premise that computer games may involve prolonged sitting, given their more interactive nature than TV viewing.[13] This is alarming given that children's LPA is only likely to decline as their sedentary time increases as they get older.[49] Thus, early intervention is necessary because LPA also has important health benefits, given its contribution to overall PA.[35]

No significant relationships were found between computer games and MVPA among girls. According to past research, girls are less likely to play computer games

than boys,[14,50-52] and more likely to engage in social sedentary behaviours,[50,53] or do homework/reading.[16,51,54] Although such behaviours were not measured in this study, it is therefore possible that social sedentary behaviours, homework and/or reading are more likely to displace MVPA among girls, which warrants further research. Despite this, our results provide support for a displacement effect while playing computer games among both sexes, especially during discretionary periods. Tailored interventions for those who engage in such behaviour for extended periods may therefore be needed.

Support for the displacement hypothesis as it pertains to the effect of computer games was also found when results were stratified by SES. In particular, time spent playing computer games was significantly negatively associated with all but one PA outcome among the high SES participants. However, significant interactions by site were found and it was apparent that in most cases a negative relationship was evident within HICs. Reasons for this are likely very complex, but it has previously been speculated that children living in HICs probably have more structure in their daily routine,[55] thus rules and restrictions may be more frequently applied. Parental rules were negatively associated with screen-viewing in a review of studies mostly conducted in Europe, North America and Oceania.[56] It is therefore plausible that high SES participants within HICs who exceeded 2 hours of computer use in the current study may have had fewer screen-viewing rules applied, and were therefore able to spend prolonged periods on their computer, at an expense to their PA. This premise is supported by results from the European Youth Heart Study, which revealed that Danish, Norwegian, and Estonian children who reported greater autonomy for their behaviour at home were more likely to spend at least 1 hour/day playing computer games.[52]

In contrast, computer use was negatively associated with only one PA outcome (LPA after school) among low SES participants across all 12 countries. In addition, there was no significant effect of computer use on overall MVPA for children within LICs, or for low SES children with HICs. This is despite evidence showing that low SES children consistently report higher levels of ST than their high SES counterparts.[56,57] Children within developing countries likely have more free time[55] and PA is more of a necessity than a lifestyle choice.[58,59] The same could be argued for low SES children within HICs because data from the UK has shown that their PA is more informal.[60,61] Data from the US on adolescent girls showed that those who spent more time home alone were more likely to be of a low SES, they did less

homework but spent more time in other sedentary activities, such as TV viewing, yet they also did more PA than girls who were supervised.[62] Consequently, such children may have more freedom and PA may be less deliberate and therefore not negatively affected by time spent in screen-based pursuits. Indeed, a recent paper found that children living in developed countries who had mothers reporting a higher level of education recorded less PA and more sedentary time than those with a lower level of education.[58] More research to support this premise is needed, and it is important to note that within some LICs, including Brazil and South Africa, our data showed negative associations between computer games and some PA outcomes among high SES children. In other research, adolescents from Brazil who typically engaged in sedentary behaviours were more likely to have a mother with a higher education level and to be from a more developed region.[63] It is therefore possible that as LICs continue to develop, similar patterns may arise in such countries. This highlights the importance of monitoring the prevalence and impact of sedentary behaviours within developing countries, particularly given that less research in this area has been done in such parts of the world.[44]

Given the potential detrimental effects on PA among those who engage in high amounts of overall ST,[15] we also sought to explore a composite measure of ST (TV viewing and computer games assessed together) and the odds associated with meeting the WHO (2010) MVPA guidelines.[25] We found that children who were meeting ST guidelines were also more likely to achieve a mean of 60 minutes MVPA per day, which concurs with another multi-national study of young people from 39 European and North American countries, though this association was stronger in some regions than others.[14] In the current study, a significant positive relationship was found in the Canadian, Finnish and South African samples only, and a negative association was found for the Chinese sample. Our findings are therefore consistent with those of Melkevik and colleagues,[14] that limiting ST may not provide a useful intervention strategy for increasing PA in all countries. Future research should seek to explain the reasons for these differences between countries.

7.5.1 Strengths and Limitations

This study has many strengths, particularly the standardised procedures and training of ISCOLE staff and quality control measures implemented across all study sites in order to ensure uniformity during data collection and to minimise bias between participating countries.[24] In addition, PA was objectively assessed using

accelerometers which are not subject to social-desirability and recall bias and enabled us to assess PA during specific times aligned with the same reference period as time spent in screen-based behaviours. However, PA may have been underestimated given that some activities, such as swimming, cannot be recorded. Other limitations must be recognised including the cross-sectional study design which limits our ability to make causal inferences regarding significant associations. Further, although Bonferroni adjusted p values were taken into account, we cannot rule out the possibility that some of our findings were due to chance, given that multiple tests were performed. Although we took into account both overall ST and individual screen-based behaviours to address the objectives of this paper, more research is needed testing the displacement hypothesis in which other sedentary behaviours are accounted for.

7.5.2 Conclusions

The results from this study lend support for the displacement hypothesis, particularly for computer games among boys, girls and children from high SES backgrounds within developed countries, and for TV viewing during discretionary periods among girls. This emphasises the need for more tailored interventions targeting specific groups, though it would seem that they are more important in some countries than others. Further research in LICs is needed, as are studies which consider other sedentary behaviours.

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Chapter 7 Closing Commentary

The results of this paper have provided support for the findings reported previously in this thesis, that time spent playing computer games may have more of a negative impact than TV viewing on children's PA. Through exploring these relationships across 12 countries by sex and SES, this final study has also provided new information. For example, TV viewing was negatively associated with girls' LPA and MVPA during discretionary periods only whereas no such relationships were found for the other groups. In addition, it was apparent from the analysis on socioeconomic differences, that a negative relationship between computer use and PA was more evident among high SES participants, within HICs.

The analyses have been repeated for the UK specifically (n=430). Several interactions by sex and SES were found, thus the results were stratified accordingly and the results are presented in Tables 1 and 2 of Appendix 6. Some similar and contrasting results have been found, which are discussed as follows.

TV viewing

Akin to the 12 country analysis, no significant negative relationships were found for TV viewing and any PA outcomes for either group, with the exception of girls' weekend MVPA (p=0.018). Those reporting the least amount of TV viewing on weekends recorded 55.7 minutes of weekend MVPA on average, versus 48.7 and 41.4 minutes for those in the middle and high TV viewing groups, respectively. Though significant differences were observed between the two extreme groups only according to Bonferroni adjusted *p* values (the Bonferroni correction was applied to minimise the risk of Type I errors aligned with multiple comparisons). In contrast, significant positive relationships were observed for boys and low SES children; those reporting the highest amount of TV viewing recorded the most amount of PA. No significant relationships were found for high SES participants.

Computer games

Significant relationships between computer games and PA outcomes were found for boys, low SES and high SES children in the UK. No significant associations were found for girls, which contrasts with the 12 country analysis, whereby significant negative relationships were reported for all LPA outcomes.

Only one significant relationship was observed for boys' MVPA after school; those who reported not playing any computer games recorded the most amount of MVPA during this period. Only one significant relationship was found for low SES participants as well; excessive computer gamers recorded the least amount of overall LPA.

Similar to the results reported across all 12 countries, computer games appeared to have more of a negative impact among high SES participants within the UK, as several significant relationships were observed for this group. Those who reported not playing any computer games at all recorded the most amount of weekend LPA, overall MVPA and MVPA after school.

Summary

These results add to those reported in Chapter 4, because they provide more contextual information about the impact of TV viewing and computer games on the PA of different groups of children, during specific times. To summarise, in Chapter 4 no relationships were observed for TV viewing and overall intensity-specific PA, whereas computer game use was negatively associated with LPA and MPA when the total sample were assessed as a whole. Here, when the results were stratified by sex and time-specific PA was also explored, TV viewing was negatively associated with girls' weekend MVPA, whereas time spent on computer games was negatively associated with boys' MVPA after school. This suggests that interventions aimed at minimising time spent on screen-based pursuits to increase PA among UK children, may need to target different behaviours for boys and girls specifically, during their free time (i.e., TV viewing for girls and computer games for boys).

Socioeconomic differences were also assessed. No significant negative relationships were found between TV viewing and PA for either SES group (in fact some positive relationships were observed for low SES children). In contrast, time spent on computer games was generally negatively associated with PA among high SES participants, whereas those of a low SES who reported excessive computer game play recorded the least overall LPA only; no other significant relationships were found for any other PA outcomes within this group. Similar reasons to those suggested in Chapter 7 could be applied here given the similarity in results reported in other developed countries for high SES versus low SES participants. Differences in social norms between socioeconomic groups, regarding rules, restrictions, and

freedom to engage in specific behaviours could be at play, which warrants further work.

CHAPTER 8

General Discussion

8.1 Overview

The overarching aim of the systematic programme of work presented within this thesis was to gain a deeper understanding of PA participation among UK children. Six empirical papers were produced, each addressing an original research question aimed at increasing the specificity of the relationships explored (i.e., looking beyond general PA levels). The purpose of this chapter is to summarise the key findings and discuss the practical implications that can be taken from these results. Possible future research directions are also provided throughout, including a discussion of the strengths and limitations of the methodology that was employed.

8.2 Summary of the Main Findings

It was evident from the first empirical chapter of this thesis (i.e., Chapter 2) that multiple lifestyle behaviours are associated with children's adiposity status. Indeed, and in the context of other research,[26,34,35,38] MVPA was consistently associated with favourable markers of body weight. It was highlighted in Chapter 4 that PA of at least a moderate intensity is likely important as no significant association was found for LPA with BMI z-score. Findings that, again, concur with past empirical research.[34,38,105] Collectively, the results of these Chapters emphasised the importance of meeting government recommended levels of MVPA because, on average, participants who achieved such standards (i.e., a mean of 60 minutes MVPA per day[53]) had a lower BMI z-score.

Despite the lower risk of overweight/obesity and other health benefits associated with MVPA[36] (e.g., cardiorespiratory fitness[106] and motor competence[43] etc.), few children and young people were found to be achieving these guidelines in Chapter 3. This was despite the fact that provision of opportunities for PA in the school and neighbourhood environments was graded favourably as part of the England Report Card (cf. Chapter 3). As such, the purpose of the following two Chapters was to explore the correlates of PA, from a multilevel perspective, so as to gain a more refined understanding of which elements of the individual, home, neighbourhood and school environments may be more conducive to PA among a sample of UK children. Within these chapters, intensity-, time- and behaviour-specific PA

outcomes were explored, in order to gain more detailed contextual information regarding the correlates associated with different types of PA, performed during specific times.

The key findings reported across these Chapters have been synthesised and a summary has been provided within the following three themes: The Complexity of Physical Activity; Demographic Differences; and Screen Time Relationships with Physical Activity.

8.2.1 The Complexity of Physical Activity

A concurrent theme of this thesis involved exploring multiple potential correlates of PA from numerous settings and levels of influence, guided by a socio-ecological model,[19] an approach referred to throughout. This coherent approach enabled a comprehensive and systematic overview of PA participation to be explored.

In Chapter 4, it was evident that multiple domains can play a role as correlates pertaining to the individual, home, and school environments were found to be associated with different intensities of activity. The results provided initial evidence of important correlates within this particular sample, including parent support, self-efficacy, participation in physically active behaviours, and school policies that promote sport participation and active transport to school. Though some were only associated with certain intensities of PA. For example, recreational computer use was negatively associated with LPA and MPA, whereas self-efficacy was positively associated with VPA only. Correlates associated with meeting the MVPA guidelines included BMI z-score (negative), and participation in physically active behaviours (sport participation, active transport, and outdoor time after school; all positive). Such information could be used in conjunction with other research, to inform interventions that are designed to promote PA in different ways (e.g., to increase total PA levels, including children's daily LPA; to promote more vigorous activity; or to improve compliance with MVPA guidelines).

It is difficult to conclude which environment or specific factors may be worth targeting the most because the results showed that several correlates from a variety of settings seem to be at play. It is also difficult to compare the results of Chapters 4 and 5 (whereby multiple influences from various settings were modelled simultaneously) with other studies that have only considered one domain. A UK study which did assess correlates from multiple domains was conducted on 7 year

old children in the North East of England.[107] Overall MVPA was the outcome of interest and correlates pertaining to the school environment were not explored,[107] thus direct comparisons cannot be drawn but some similar findings were reported that are still worth discussing. Correlates of overall MVPA that concur with our results included male sex (positive), overweight/obesity (negative), and active transport to school (positive). Additional correlates, not assessed in our study, included child interest in active play (positive), and the season (i.e., MVPA was higher in summer).[107] Their results, in accordance with ours, emphasise the importance of accounting for individual differences, given that at least one individual/demographic correlate was associated with all outcomes across Chapters 4-6 in this thesis. Taken together, the results of our work and that of King et al,[107] also reiterate the positive contribution that active transport to school can make towards MVPA because active transport was positively associated with MPA, VPA, and meeting the MVPA guidelines in Chapter 4 in addition to MVPA during all time periods in Chapter 5.

MVPA recorded during specific times (after school, before school and on weekends) was assessed in Chapter 5 and correlates of outdoor time during discretionary periods (after school and on weekends) were analysed in Chapter 6. The results from both of these Chapters supported the premise that correlates beyond the home environment may have more of an impact on weekend days,[60,108] because none of the home environment variables that were tested were associated with weekend MVPA or weekend outdoor time. Whereas, correlates related to the neighbourhood environment (i.e., access to playing fields, access to parks, and crime-related safety concerns) were found to be associated with weekend MVPA in Chapter 5. Families with children of this age group may be more likely to spend the weekend together on trips away, elsewhere.[109] In addition, none of the school environment correlates were found to be associated with MVPA conducted outside of school hours. There may be other potential correlates at play that were not explored in this study (e.g., access to facilities and equipment, other active transport policies etc.), especially given that almost all schools (> 97%) provide extra-curricular activities in sport and PA (2015 YST; unpublished custom analysis), according to the school environment results of Chapter 3. Nevertheless, these findings indicate that specific environments may be worth targeting during particular times.

Collectively, our results support the basis of the socio-ecological model developed by Sallis and colleagues,[19] in that they demonstrate the complexity and multifaceted

nature of children's PA participation. Considering the results as a whole, it could be concluded that a more holistic approach to future interventions, which look to target several settings in different ways to increase PA, using an 'additive' approach, may be worthwhile. To illustrate, if small changes are made in the school, home, and neighbourhood environments at specific times, when they could have the largest effect, each setting could contribute to small increases in PA across the whole day, which might accumulate to health benefits. This concept is supported by Kellou et al,[110] who conducted a review on the effectiveness of intervention studies designed to increase PA and subsequently prevent weight gain. Interventions which incorporated strategies targeting several levels of influence, as opposed to just one or two levels, were significantly more likely to demonstrate improvements in at least one marker of adiposity.[110] Furthermore, the majority of interventions included in their review were school-based and although they helped to increase PA during school time, they had a limited impact on children's overall PA levels.[110] Similar findings were reported in a review conducted by Wang et al,[75] because school-based interventions that included a home and/or community component, were the most successful in terms of their effect on obesity prevention. This could explain why past interventions have had limited success in the past, because only one aspect of a child's environment is usually targeted.[75] Multi-component interventions which incorporate strategies within the school, home, and neighbourhood environments may therefore be worthwhile. Future applied research would do well to test whether such a multifaceted and time-segmented approach holds merit.

8.2.2 Demographic Differences

In the General Introduction of this thesis, it was noted that work is required to gain insight into how factors within the socio-ecological model interact or relate to one another and how they differ according to specific groups of children. Consequently, age, sex, and SES were included as correlates, as opposed to covariates, in Chapter 5; interactions by sex and SES were explored in Chapter 6; and results were stratified by sex and SES in Chapter 7. The attention now turns to some of the key differences that were observed between these groups.

It was evident that boys did more MVPA than girls in general (i.e., across all time periods explored in Chapter 5). This is consistent with the findings from Chapter 3 as boys were typically in a higher grade boundary (grade D) than girls (grade F), for the proportion of children meeting MVPA guidelines, according to nationally representative data (e.g.,[52,71]). Boys also reported more time outdoors after school

in Chapter 6 but no sex differences were observed for this behaviour on weekend days. Yet, a significant age*sex interaction was found which showed that an increase in age was associated with higher odds of weekend outdoor time among girls. The same interaction and relationship was apparent among high SES participants. Although independent mobility was not measured in the ISCOLE study, similar findings can be drawn from past research in relation to this, which could be closely related to our findings. Not only has independent mobility been consistently associated with more time outdoors[111,112] and PA,[60,109,113] but it is typically higher among boys.[109,112,113] Children living in deprived areas, or considered to be of a low SES, have also reported higher independent mobility,[114-116] despite reports of greater traffic- and crime-related safety concerns in a UK study.[114] It is therefore plausible to suggest that boys and low SES participants may have had greater freedom to roam outdoors than girls and their high SES counterparts, respectively. As children have more free time on weekend days they have the potential to spend longer outside and to subsequently travel further away from home. This could explain the importance of age among girls and high SES participants over the weekend because independent mobility is also typically higher among older children.[115-117]

Interestingly, similar group differences were found in Chapter 7; screen-based behaviours appeared to displace time spent in PA among girls and high SES children, across 12 countries, more so than they did among boys and those of a low SES background. For instance, both TV viewing and computer use was negatively associated with girls' PA, whereas boys who watched excessive amounts of TV (≥ 3 hours/day) recorded more LPA and MVPA overall than those who watched TV for less time. However, negative relationships were observed for computer games among boys with LPA/MVPA during their free time. As for SES differences, a negative relationship was observed between computer use and all but one PA outcome among those of a high education. In contrast, only one significant negative relationship was observed for low SES participants between computer use and LPA after school.

This socioeconomic divide was more apparent within HICs, including the UK specifically as shown in the post-commentary text of Chapter 7. The reasons for these differences are largely unknown and likely to be complex. However, it was speculated that differences in social norms and attitudes regarding parental rules and restrictions between socioeconomic groups could be at play, as well as

differences in children's daily routines. For example, PA is accumulated differently among children from low and high income countries. The former accumulate their activity through less deliberate means (e.g., via active transport), whereas the latter tend to engage in more structured sport and PA.[100] Perhaps a similar pattern is occurring between boys/girls and low/high SES children within developed countries. Boys and low SES children may be engaging in less intentional and more informal PA during their free time (potentially in relation to a greater level of independent mobility), which may not be impacted by other competing interests, such as TV viewing. Such mechanisms need to be explored in future research as they could provide important information for interventions aimed at particular groups. Such group differences, and other consistently reported mechanisms in the literature, should be incorporated into the socio-ecological model in future, as new research comes to light.

8.2.3 Screen Time Relationships with Physical Activity

Relationships between screen-based behaviours and PA were tested throughout the thesis. Access to electronic media devices was also examined but some contradictory results were found across Chapters 4-6. Ownership of a mobile phone was negatively associated with LPA in Chapter 4 in the unadjusted analysis, but this did not remain significant in the final model. The presence of a TV in the child's bedroom was negatively associated with MVPA before school in Chapter 5. Whereas this and access to a non-hand held video game player in the bedroom, were associated with greater odds of time outdoors after school in Chapter 6. In addition, children with access to a low number of media devices overall spent less time outdoors after school.

On the whole, it would seem that negative associations were found for PA outcomes, and positive relationships were apparent for time spent outdoors. Although fewer relationships were tested with PA specifically, they have been elsewhere within the ISCOLE sample, across all 12 countries.[118] Indeed, in the work of Harrington et al,[118] negative relationships were found between the presence of media devices in the child's bedroom and MVPA during specific times. Yet, this association was not significant for the presence of a TV in the bedroom, or for devices that can be used outside of the bedroom, and those with more TVs in the house overall did more MVPA on weekends.[118] Pouliou et al,[119] reported a positive relationship between having a TV in the bedroom and PA among seven year old children in the UK. In both of these studies, the authors speculated that ownership

of a TV in the child's bedroom could be acting as a marker of socioeconomic differences in PA.[118,119] It is possible that the same mechanism was at play in our work, particularly for the observed relationships with outdoor time after school because low SES participants reported more time outdoors during this period than high SES children. However, no significant interactions by SES, for the relationships between media access variables and outdoor time, were found in our study. Other possible reasons for the counterintuitive findings were proposed in Chapter 6. For example, it was speculated that children with access to few electronic devices in the home may have other restrictions in place, such as not being allowed outside to play, which in turn might result in less time spent outdoors. Alternatively, it may be that children with few electronic devices have preferences for other indoor activities (e.g., reading or drawing etc.) that may compete for time spent outdoors. Such mechanisms should be tested in future work utilising mediation analyses.

Contrasting results were also reported across Chapters 4-7 for time spent engaging in screen-based behaviours. No significant associations were found for LPA, MPA, VPA, or meeting the MVPA guidelines and TV viewing in Chapter 4, nor was there a significant relationship with MVPA during specific time periods when both computer use and TV viewing were included as a composite measure of ST in Chapter 5. In contrast, time spent on computer games was negatively associated with LPA and MPA in Chapter 4, and with outdoor time after school in Chapter 6. It would therefore seem that computer use may have more of an effect than TV viewing, in terms of competing for time outdoors or in PA. These relationships were examined in more detail in the final Chapter, according to sex and SES, within a larger sample of children. Again, computer use appeared to have more of an effect than TV viewing because negative relationships were observed across all groups for at least one PA outcome for this behaviour. Whereas, TV viewing was only negatively associated with girls' PA, during discretionary periods.

It is plausible to suggest that our measure of computer use may have captured time spent playing on multiple devices because participants were asked how long they spent on a computer to either play games or for any other recreational use. Given that children now have access to multiple electronic devices including tablet computers, video game players, e-readers, and smartphones etc., these may have been taken into account in participant's responses. This could explain the higher number of significant negative relationships observed for computer use. In addition, differences between computer use and TV viewing may be due to the 'active' and

'passive' nature of such behaviours, respectively.[28] Computer games or use of the internet and social media etc. require more interaction, time and attention. In comparison, TV viewing may be disrupted by adverts and determined by the length of the programme, providing more opportunities for time outdoors or physically active behaviour. In other research, mothers have reported that rules for TV are not needed because their children's attention span is not long enough to sit and watch TV for an excessive amount of time.[120]

It would seem from our results overall, that the displacement hypothesis may be more applicable to recreational computer use specifically, as it may involve prolonged periods of sitting, which could have implications for children's lighter-intensity activity in particular. However, TV viewing has been associated with unhealthy dietary patterns,[30] thus minimising time spent in this behaviour may still be important. Research that explores differences according to specific groups is required to support these findings and data on other screen and non-screen based behaviours is needed.

8.3 Practical Implications of the Findings

Bauman et al[66] argued that the biggest challenge now posed to health researchers is the ability to translate findings into successful interventions and effective public health policies. Several potential strategies in relation to the results of this research have been discussed throughout the thesis. For the Report Card in particular, several key recommendations were proposed, which were presented within infographics (see www.activehealthykidsengland.co.uk) for each of the nine indicators that were assessed as part of this work. A summary of the key practical implications that can be taken from this thesis are provided here.

8.3.1 Compliance with Behavioural Guidelines

Although the focus of this thesis is on PA behaviour, it is noteworthy that children should comply with guidelines for multiple lifestyle behaviours, as per the results for Chapter 2. It was evident from significant interactions for PA*sleep and ST*sleep, that children who did not meet guidelines for both behaviours recorded the highest BMI z-score on average. Campaigns that aim to raise awareness of behavioural guidelines may prove useful, as a previous study showed that girls who were more aware of the PA guidelines were more likely to achieve them.[73]

It was noted in Chapter 3, that guidelines for sedentary behaviour are needed in the UK. Although, screen-based behaviours have been included in all studies across the thesis to examine whether such behaviours can displace PA, it is still too early to recommend a limit that should be applied. Current guidelines, implemented in Canada, state that children should limit their recreational ST to less than 2 hours per day.[96] Ogunleye and colleagues[121] have argued for the same guidelines to be applied in the UK. They also recommended an absolute maximum limit of 4 hours per day, because they found a dose-response relationship between ST and PA among a large sample of youth in England.[121] Children with excessive screen use overall (≥ 4 hours/day) may be at the highest risk of low PA levels.[121,122] A similar dose-response relationship was observed in Chapter 7 but, as mentioned previously, this was more apparent for computer use; only girls who watched the most amount of TV recorded significantly lower PA levels, and differences between groups were small. This suggests that different screen-based behaviours may have contrasting effects, and only certain screen-based pursuits may be problematic, and more so among specific groups of children. Accordingly, it could be concluded that limiting screen-based behaviours may only be a useful intervention strategy as part of a larger effort to increase children's PA.

One solution is to adapt an English version of the recently published Canadian 24-hour movement guidelines,[96] in an effort to promote healthier lifestyles overall. These guidelines now include recommendations for sleep, LPA, MVPA, and VPA as well as sedentary behaviour (including recreational ST and advice to limit prolonged periods of sitting), covering the whole 24-hour period.[96] Akin to the suggestion made earlier, that holistic interventions targeting multiple settings may provide an effective solution, encouraging children to achieve several behavioural targets throughout the day is also likely to add up to larger health benefits.[32]

8.3.2 Promoting Physical Activity as a Way of Life

In terms of meeting the MVPA guidelines specifically, it was evident from Chapters 4 and 5 that physically active behaviours (such as active transport, organised sport, and spending time outdoors) are important as they were consistently associated with different PA outcomes. In particular, they were all independently associated with meeting the MVPA guidelines in Chapter 4.

It was concluded that participation in at least one of these behaviours may therefore provide benefits. However, a limitation of this Chapter was that children were

categorised as meeting the guidelines if they achieved a *mean* of 60 minutes MVPA per day. When you consider that the guidelines specify the need to accumulate 60 minutes of MVPA on *all seven days* of the week, it is more likely that children are going to achieve this if they are engaging in several physically active behaviours throughout the day. This recommendation has been proposed by Tremblay and associates,[100] as they argued that PA should be encouraged as a way of life, accumulated from a variety of sources and not solely from structured activity, which is typically the case in developed countries. This is of particular significance in England since children and adolescents have become increasingly sedentary, with few engaging in activity on a daily basis (i.e., in 2015, less than half (41%) of children reported walking to school as their main mode of travel[123] and a low proportion of children are reportedly engaging in frequent active play[124]), as highlighted in Chapter 3. Plus the majority of provision in schools or the neighbourhood is geared toward structured activity,[77] yet informal active play contributed the most to PA in a study of active children across England.[125] Future policy could be guided by other countries, such as the Netherlands, where they have managed to successfully implement strategies which incorporate PA as a way of life, through a variety of means.[100] In addition, providing examples of what constitutes as LPA, MVPA and VPA in PA guidelines, by incorporating the types of PA that children can do to achieve sufficient amounts of PA throughout the day, may be more meaningful to the general public.

8.3.3 Socioeconomic Disparities in Physical Activity

Although the results of Chapter 3 showed that the majority of children are insufficiently active, it is clear that certain groups may need special attention (e.g., girls and overweight/obese children), and interventions may need to be tailored differently to them. For example, girls may face barriers to their independent mobility, seen as they are typically given less freedom to roam than boys[109] (as discussed in Chapter 6), or they may have different preferences for specific types and intensities of PA.[65] Whereas overweight and obese individuals have been shown to experience greater body image concerns compared to non-overweight children,[126] and other barriers to PA can include a lack of social support and low perceived competence.[127] Such issues would need to be taken into account when targeting specific groups.

In terms of socioeconomic differences in PA, the results are less clear. Low SES participants recorded more MVPA after school in Chapter 5. They also reported

higher odds of time outdoors during this time period in Chapter 6. This suggests that these individuals could be getting their activity at this time through informal PA,[128] such as active play, which is typically performed outside.[104] However, no SES differences were found for overall measures of intensity-specific PA in Chapter 4, or for MVPA and outdoor time at the weekend in Chapters 5 and 6, respectively. Other null findings have been reported elsewhere among children.[129] Voss and colleagues[128] found that children from low income families were not necessarily less active than their high SES counterparts even though they were less likely to engage in formal/organised sports. These children made up for this through informal active play instead.[128] It would appear that SES disparities are more prevalent among adolescents, with those from high SES backgrounds frequently reporting more time in PA than those of a low SES background.[64,129,130] This may be because children's inherent nature to play declines as a function of biological maturation.[131] Consequently, it may be that those from low SES backgrounds may not be replacing their active play with formal sports as they go through adolescence, rendering them insufficiently active which could have implications for their health. Longitudinal studies that follow children through adolescence, from different socioeconomic backgrounds is needed to confirm this. Reasons for any lack of uptake in organised sport beyond financial limitations, as is typically proposed,[64,129] need exploring.

8.4 Future Research Directions

Several suggestions for future research have been proposed throughout this thesis. As opposed to restating these suggestions, some key directions that have not yet been mentioned in this chapter are provided within this section.

First, more research is needed within UK samples of children on correlates associated with meeting the MVPA guidelines because the majority of research exploring this has either been conducted in other European countries or among US samples of children or adolescents (e.g.,[132-137]). Most of these have used self-reported measures with different definitions of what constitutes as compliance with guidelines, and socio-demographic correlates (e.g., age, sex, and SES) have predominantly been explored in isolation. An exception is a UK study that looked at correlates from multiple domains on seven year old children.[119] The authors only found markers of SES, including maternal education and car ownership, to be negatively associated with 60 minutes of MVPA per day, derived from accelerometry.[119] These results contrast with our findings as SES was not

associated with meeting the MVPA guidelines in Chapter 4, but maternal and paternal education levels were not explored separately which could explain these differences. A study on German children, which included multiple domains, also found positive associations between sport participation and outdoor play with adherence to PA guidelines.[133] However, PA was self-reported and they defined adherence as 60 minutes of MVPA on at least 4 days per week.[133] Nevertheless, this further supports the importance of encouraging participation in physically active behaviours, to help children achieve sufficient levels of MVPA per day. Other work on UK samples of children, utilising objective measures of MVPA are needed.

It has already been discussed how PA should be incorporated into children's everyday lives but it is important to mention that this likely depends on external factors pertaining to children's independent mobility and the built environment. For example, Biddle et al,[65] argued that the amount of time spent outdoors likely interacts with environmental factors, such as access to facilities, aesthetics, parental influences etc. Parental safety concerns were assessed in Chapters 5 and 6 of this thesis and the results suggest that crime- and traffic-related concerns may have an impact on children's PA in different ways according to the specific behaviour, time, or group in question. Previous research has failed to find an association between safety concerns and PA,[64] and this may be because context-specific outcomes have typically not been taken into account. As such, further research that looks at relationships more closely, including interactions and context-specific outcomes is needed, to corroborate the findings reported here.

In terms of the built environment, segregated cycle paths and traffic calming measures were suggested in Chapter 3 as a means of encouraging increased cycling and active travel, as this is one of the key policies implemented successfully in the Netherlands.[138] In addition, facilities that are designed for the purpose of engaging in informal PA (i.e., playing fields, tennis courts, etc.) that are close to home may be worthwhile promoting because facilities of this kind were positively associated with MVPA on weekend days in Chapter 5. Still, additional research is needed to support this and objective measurements of the built environment are required to advance knowledge in this field.

Finally, participation in screen-based behaviours has been assessed throughout, and it has consistently been noted that more research on other screen-based pursuits is needed. However this presents certain challenges, as noted by Ogunleye et al,[121] because the rapid developments of new technologies can quickly lead to

outdated research. Tools to deal with this and innovative research methods are essential to overcome such issues and other non-screen based sedentary behaviours also warrant further work.

8.5 Strengths and Limitations of this Research

A major strength of the studies carried out in this thesis is the multilevel framework and specificity of research that has been conducted, in order to gain more contextualised information. Multiple lifestyle behaviours were assessed simultaneously in Chapter 2 while several environments and different levels of influence were analysed in Chapters 3-5. The purpose of Chapters 6 and 7 was to hone in on specific relationships while considering differences between subgroups, to expand on the research conducted in Chapters 4 and 5. The final chapter in particular included data from 12 countries, which varied widely in terms of their socioeconomic, cultural and geographic characteristics.[1] The rigorous training and quality control procedures that were employed as part of ISCOLE helped to minimise bias and ensured consistency in data collection procedures between sites.[1]

A mixture of objective and subjective measures were utilised throughout, and in particular different behaviours conducted at specific times were measured, which enabled a more detailed analysis of the context being explored. However, there are limitations with both these measures, in that self-reported data come with the potential for social-desirability and recall bias. Accelerometry data does not capture water-based exercise such as swimming, nor can it capture cyclical movements, such as riding a bike, accurately. Thus, PA may have been underestimated.

Other limitations consistently highlighted throughout, include the predominantly white British sample from one region of the UK, and cross-sectional study design. The former limits the generalisability of findings to other ethnic groups and children within other regions across the UK, while the latter does not allow inferences to be made regarding the direction of observed relationships. Longitudinal data are therefore needed. Studies which follow children through their adolescent years would be useful to see how patterns in behaviour change, as they move from primary to secondary school because changes in PA have previously been shown to occur during this transition period.[132,139]

Although efforts were made to include potential important covariates throughout this thesis, it is not possible to control for all influencing factors. Despite this, a key strength of the statistical analyses performed throughout, is the use of multilevel modelling techniques to control for potential clustering effects among children at the same school. Interactions were also explored to assess group differences according to specific demographic characteristics, but other analyses, including mediation, should be employed in future, to explore potential underlying mechanisms.

It is also important to highlight that although efforts were made to minimise missing data, some differences between the included and excluded participants were found. Listwise deletion of participants with missing data is generally not recommended if data are not missing completely at random because this can result in reduced power and biased estimates.[140] Techniques such as multiple imputation should be considered in future work to overcome this issue, where it is deemed appropriate.

All data presented in this thesis are quantitative, which does not offer the same flexibility and opportunities to explore ideas in more depth that can be provided from qualitative data. Qualitative studies that examine some of the potential mechanisms discussed in this thesis might provide novel and insightful interpretations not covered here or previously thought.

8.6 Conclusions

In conclusion, it is clear that PA among children is a complex, multifaceted behaviour which can be influenced by numerous factors from a number of different settings that may affect specific groups of children in different ways. It would therefore be easy to get carried away with interventions that aim to change lots of different things all at once. However, it could be argued based on the collective results of this thesis that small increases in PA accumulated throughout the day, via different means, to encourage PA as a way of life may offer a suitable solution. Schools and Local Authorities should work together with parents and families, to create better opportunities for informal activity during children's free time. That said, more research is still needed to ascertain the best approaches for this at all levels of influence, and although these studies have provided novel insight towards the socio-ecological model, there are still numerous areas to explore.

It is hoped that some of these findings can be used in conjunction with previous and emerging research, to inform future research directions as well as successful

intervention studies. In turn, it is hoped that eventually a decline in childhood obesity rates will be seen, including a paradigm shift to physically active lifestyles among children and youth in developed countries, such as the UK, and across the world.

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APPENDICES

Participant ID (attach label here)	Technician Initials ☐☐☐ Date ☐☐ / ☐☐☐ / ☐☐☐☐

Questionnaire administered by: Interviewer ☐ Self-administered ☐

Appendix 1: ISCOLE Diet and Lifestyle Questionnaire

Please read every question carefully. What answer comes to your mind first?
Choose the box that fits your answer best and fill it in.

Remember: This is not a test so there are no wrong answers. It is important that you answer all the questions and also that we can see your marks clearly.

You do not have to show your answers to anybody.
Also, nobody who knows you will look at your questionnaire once you have finished it.

For the questions on this page, please tell about what you did *last week*.

1. On a school day, how many hours did you watch TV?

☐ I did not watch TV on school days ☐< 1 hour ☐1 hour ☐2 hours ☐ 3 hours ☐4 hours ☐ 5 or more hours

2. On a school day, how many hours did you play video or computer games or use a computer for something that was not school work?

☐ I did not play video/computer games or use a computer other than for school work on school days ☐< 1 hour ☐1 hour ☐2 hours ☐ 3 hours ☐4 hours ☐ 5 or more hours

3. On a school day how much time did you spend outside **before** school?

☐ < 1 hour ☐ 1 hour ☐ 2 hours ☐ 3 hours ☐ 4 hours ☐ 5 or more hours

4. On a school day how much time did you spend outside **after** school before bedtime?

☐ < 1 hour ☐ 1 hour ☐ 2 hours ☐ 3 hours ☐ 4 hours ☐ 5 or more hours

5. On a weekend day, how many hours did you watch TV?

☐ I did not watch TV on weekend days ☐< 1 hour ☐1 hour ☐2 hours ☐ 3 hours ☐4 hours ☐ 5 or more hours

For official use only. ISCOLE QUALITY CONTROL (QC) and DATA ENTRY:

QC Staff Initials: _____ Date: _____ / _____ / _____

Data Entry Staff Initials: _____ Date: _____ /_____ / _____

Participant ID (attach label here)	Technician Initials ☐☐☐ Date ☐☐ / ☐☐☐ / ☐☐☐☐

Questionnaire administered by: Interviewer ☐ Self-administered ☐

6. On a weekend day, how many hours did you play video or computer games or use a computer for something that was not school work?

☐ I did not play video/computer games or use a computer other than for school work on the weekend ☐< 1 hour ☐1 hour ☐2 hours ☐3 hours ☐4 hours ☐5 or more hours

7. On a weekend day, how much time did you spend outside?

☐ < 1 hour ☐ 1 hour ☐ 2 hours ☐ 3 hours ☐ 4 hours ☐ 5 or more hours

8. In the last week you were in school, on how many days did you go to physical education (PE) classes?

☐ 0 days ☐ 1 day ☐ 2 days ☐ 3 days ☐ 4 days ☐ 5 days

9. In the last week you were in school, the **MAIN** part of your journey to school was by:

☐ walking
☐ bicycle, roller-blade, skateboard or scooter
☐ bus, train, tram, underground or boat
☐ car, motorcycle or moped
☐ other _____

10. In the last week you were in school, **HOW LONG** did it take you to travel to school?

☐ < 5 minutes ☐ 5 - 15 minutes ☐ 16 - 30 minutes ☐ 31 minutes to 1 hour ☐>1 hour

11. During the past year (12 months), did you do any of these activities? (Check all that apply)

☐ sports teams ☐ dance / martial arts class ☐ art / music class ☐ none of these

12. During the past week (7 days), on how many days were you physically active for a total of at least 60 minutes per day? (all the time you spent in activities that increased your heart rate and made you breathe hard)

☐ 0 days ☐ 1 day ☐ 2 days ☐ 3 days ☐4 days ☐5 days ☐6 days ☐7 days

For official use only. ISCOLE QUALITY CONTROL (QC) and DATA ENTRY:

QC Staff Initials: _____ Date: _____ / _____ / _____

Data Entry Staff Initials: _____ Date: _____ /_____ / _____

Participant ID (attach label here)	Technician Initials ☐☐☐ Date ☐☐ / ☐☐☐ / ☐☐☐☐

Questionnaire administered by: Interviewer ☐ Self-administered ☐

Please tick the box that most sounds like you:	**Disagree a Lot → Agree a Lot**				
	1	**2**	**3**	**4**	**5**
13. I can be physically active during my free time on most days.	☐	☐	☐	☐	☐
14. I can ask my parent or other adult to do physically active things with me.	☐	☐	☐	☐	☐
15. I can be physically active during my free time on most days even if I could watch TV or play video games instead.	☐	☐	☐	☐	☐
16. I can be physically active during my free time on most days even if it is very hot or cold outside.	☐	☐	☐	☐	☐
17. I can ask my best friend to be physically active with me during my free time on most days.	☐	☐	☐	☐	☐
18. I can be physically active during my free time on most days even if I have to stay at home.	☐	☐	☐	☐	☐
19. I have the coordination I need to be physically active during my free time on most days.	☐	☐	☐	☐	☐
20. I can be physically active during my free time on most days no matter how busy my day is.	☐	☐	☐	☐	☐

There are lots of reasons why people take part in physical activity. Please tick the box to show how much each of the reasons below is true for you:

	never true for me	a little bit true for me	sometimes true for me	true for me	very true for me
21. I take part in exercise because other people say I should	☐	☐	☐	☐	☐
22. It's important to me to exercise regularly	☐	☐	☐	☐	☐
23. I can't see why I should bother exercising	☐	☐	☐	☐	☐
24. I feel like a failure when I haven't exercised in a while	☐	☐	☐	☐	☐
25. I find exercise a pleasurable activity	☐	☐	☐	☐	☐

<u>For official use only.</u> ISCOLE QUALITY CONTROL (QC) and DATA ENTRY:

QC Staff Initials: _____ Date: _____ / _____ / _____

Data Entry Staff Initials: _____ Date: _____ / _____ / _____

Participant ID (attach label here)	**Technician Initials** ☐☐☐ **Date** ☐☐ / ☐☐☐ / ☐☐☐☐

Questionnaire administered by: Interviewer ☐ Self-administered ☐

26. During the past week, what time have you usually turned out the light and gone to sleep on school days?

☐☐:☐☐ AM / PM (circle AM or PM)

27. During the past week, at what time have you usually woken up in the morning on school days**?**

☐☐:☐☐ AM / PM (circle AM or PM)

28. During the past week, what time have you usually turned out the light and gone to sleep on weekend days?

☐☐:☐☐ AM / PM (circle AM or PM)

29. During the past week, at what time have you usually woken up in the morning on weekend days?

☐☐:☐☐ AM / PM (circle AM or PM)

30. During the past week, how would you rate your sleep **quality** overall (how **well** you sleep)?
☐ very good ☐ fairly good ☐ fairly bad ☐ very bad

31. During the past week, how would you rate your sleep **quantity** overall (how **much** you sleep)?
☐ very good ☐ fairly good ☐ fairly bad ☐ very bad

32. Do you have a television in your bedroom?

☐ Yes ☐ No

33. How many times do you usually eat . . . ? (Please mark only one box for each line)

	Never	Less than once a week	Once a week	2-4 days a week	5-6 days a week	Once a day, every day	Every day, more than once
Fruits	☐	☐	☐	☐	☐	☐	☐
Vegetables	☐	☐	☐	☐	☐	☐	☐
Sweets/chocolate	☐	☐	☐	☐	☐	☐	☐
Regular cola or soft drinks that contain sugar	☐	☐	☐	☐	☐	☐	☐
Cake, pastries, or donuts	☐	☐	☐	☐	☐	☐	☐

For official use only. ISCOLE QUALITY CONTROL (QC) and DATA ENTRY:

QC Staff Initials: _____ Date: _____ / _____ / _____

Data Entry Staff Initials: _____ Date: _____ / _____ / _____

Participant ID (attach label here)	**Technician Initials** ☐☐☐ **Date** ☐☐ / ☐☐☐ / ☐☐☐☐

Questionnaire administered by: Interviewer ☐ Self-administered ☐

Diet cola or diet soft drinks	☐	☐	☐	☐	☐	☐	☐
Crisps	☐	☐	☐	☐	☐	☐	☐
Chips/French fries	☐	☐	☐	☐	☐	☐	☐
Dark green vegetables (broccoli, spinach, etc.)	☐	☐	☐	☐	☐	☐	☐
Orange vegetables (carrots, squash, sweet potato, etc.)	☐	☐	☐	☐	☐	☐	☐
Fruit juice	☐	☐	☐	☐	☐	☐	☐
Low fat milk (semi-skim/ skimmed)	☐	☐	☐	☐	☐	☐	☐
Full fat/whole milk	☐	☐	☐	☐	☐	☐	☐
Cheese	☐	☐	☐	☐	☐	☐	☐
Other milk products (yogurt, chocolate milk, pudding, etc.)	☐	☐	☐	☐	☐	☐	☐
Whole grain bread or cereal (porridge, muesli, etc.)	☐	☐	☐	☐	☐	☐	☐
Meat alternatives (beans, lentils, tofu, eggs, peanut butter, etc.)	☐	☐	☐	☐	☐	☐	☐
Energy drinks (Red Bull, etc.)	☐	☐	☐	☐	☐	☐	☐
Sports drinks (Lucozade, Gatorade, Powerade, etc.)	☐	☐	☐	☐	☐	☐	☐
Fish	☐	☐	☐	☐	☐	☐	☐
Ice cream	☐	☐	☐	☐	☐	☐	☐
Fried food such as chicken wings, chicken nuggets, chicken fingers, etc.	☐	☐	☐	☐	☐	☐	☐
Fast foods such as pizza, burgers, etc.	☐	☐	☐	☐	☐	☐	☐

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34. How many times do you usually eat the following food items **while watching television**?

	Never	Less than once a week	Once a week	2-4 days a week	5-6 days a week	Once a day, every day	Every day, more than once
Crisps or peanuts	☐	☐	☐	☐	☐	☐	☐
Fried food such as chicken wings, chicken nuggets, chicken fingers, etc.	☐	☐	☐	☐	☐	☐	☐
Cookies, biscuits, chocolate or sweets	☐	☐	☐	☐	☐	☐	☐
Ice cream	☐	☐	☐	☐	☐	☐	☐
Fast foods such as pizza, burgers, etc.	☐	☐	☐	☐	☐	☐	☐
Fruits or vegetables	☐	☐	☐	☐	☐	☐	☐

35. How often do you usually have **breakfast** (more than a glass of milk or fruit juice)? Mark one box for weekdays and one box for weekend.

Weekdays

- ☐ I never have breakfast on weekdays
- ☐ One day
- ☐ Two days
- ☐ Three days
- ☐ Four days
- ☐ Five days

Weekend

- ☐ I never have breakfast on the weekend
- ☐ I usually have breakfast on only one day of the weekend (Saturday OR Sunday)
- ☐ I usually have breakfast on both weekend days (Saturday AND Sunday)

36. Does your school serve school lunches?

☐ Yes ☐ No

37. In the last week you were in school, about **how many times a week** did you eat a school lunch?

☐ 0 days ☐ 1 day ☐ 2 days ☐ 3 days ☐ 4 days ☐ 5 days

38. During the past week**,** how many meals (breakfast, lunch or dinner) did you get that were **prepared away from home** in places such as restaurants, fast food places, food stands, grocery stores or vending machines? (please do not include meals provided as part of school breakfast or school lunch)

☐☐ meals

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How well do these statements describe you? (Put a mark in the box that best describes how often this happens).

	Never or Almost Never	Sometimes	Usually or Always
39. When I am worried I eat more	☐	☐	☐
40. I eat when I am angry/cross	☐	☐	☐
41. When I do something well I give myself a food treat	☐	☐	☐
42. When I am sad I eat more	☐	☐	☐
43. When I am happy I eat more	☐	☐	☐
44. When I am bored I eat more	☐	☐	☐
45. I eat between meals even when I am not hungry	☐	☐	☐

Thinking about the last week….. (Put a mark in the box that best describes how you felt)

	Not at all	Slightly	Moderately	Very	Extremely
46. Have you felt fit and well?	☐	☐	☐	☐	☐
47. Have you felt full of energy?	☐	☐	☐	☐	☐
48. Have you felt sad?	☐	☐	☐	☐	☐
49. Have you felt lonely?	☐	☐	☐	☐	☐
50. Have you had enough time for yourself?	☐	☐	☐	☐	☐
51. Have you been able to do the things you want to do in your free time?	☐	☐	☐	☐	☐
52. Have your parent(s) treated you fairly?	☐	☐	☐	☐	☐
53. Have you had fun with your friends?	☐	☐	☐	☐	☐
54. Have you got on well at school?	☐	☐	☐	☐	☐
55. Have you been able to pay attention?	☐	☐	☐	☐	☐

56. In general, how would you say your health is?

☐ excellent ☐ very good ☐ good ☐ fair ☐ poor

Thank you

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Appendix 2: ISCOLE Demographic and Family Health Questionnaire

A. GENERAL INFORMATION

Child's Name:

Last First Middle

Name of Child's School:

Parent's or Guardian's Name:

Last First Middle

Home Address:

Street Address Flat/House number Town or City County Postcode

Phone Number: ( ) E-Mail:

Area Code

How long have you lived at the current address? _____years and _____months

B. DEMOGRAPHICS OF CHILD

Birth date _____/_____/_____ Age _____years Gender: ☐ Male ☐ Female
dd/mmm/yyyy (e.g., 06/Jul/2011)

Ethnicity **–** Please select the One that applies to you:

<u>White</u>

- ☐ White English/Welsh/Scottish Northern Irish/British
- ☐ White Irish
- ☐ Gypsy or Irish Traveller
- ☐ Any other White background, please state: _____

<u>Mixed / multiple ethnic groups</u>

- ☐ White and Black Caribbean
- ☐ White and Black African
- ☐ White and Asian
- ☐ Any other Mixed / multiple ethnic background, please state:_____

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Asian/ Asian British

- ☐ Indian
- ☐ Pakistani
- ☐ Bangladeshi
- ☐ Chinese
- ☐ Any other Asian background, please state:_____

Black / African / Caribbean / Black British

- ☐ African
- ☐ Caribbean
- ☐ Any other Black / African / Caribbean background, please state:_____

Other ethnic group

- ☐ Arab
- ☐ Any other ethnic group, please state:_____

Are you of Hispanic origin? ☐ Yes ☐ No

In what country was the child born? _____

How many biological brothers and sisters does the child have? _____

What are their ages? _____yrs _____yrs _____yrs _____yrs _____yrs
_____yrs _____yrs _____yrs _____yrs _____yrs

C. HEALTH HISTORY OF CHILD

1. Birth Weight: ___lbs & ____oz OR _____kg Birth Length: _____inches OR_____cm

2. Length of Pregnancy: _____weeks OR _____months

3. Did mother develop gestational diabetes during pregnancy with **THIS** child?

☐ Yes ☐ No

4. Fed breast milk? ☐ Yes ☐ No If No, please skip to question 5.

Age when **COMPLETELY** stopped being fed breast milk: _____months

Age when **FIRST** fed formula: _____months

5. Age when **COMPLETELY** stopped drinking formula: _____months

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D. FAMILY DEMOGRAPHICS AND HEALTH

6. What is the marital status of the child's parents?

- ☐ Married
- ☐ Divorced or separated
- ☐ Never married
- ☐ Widowed parent

7. How many people live in your household (at this address)? ____

7a. Who lives with the child **at this address** (check all that apply)?

- ☐ Biological Mother
- ☐ Biological Father
- ☐ Adoptive Mother
- ☐ Adoptive Father
- ☐ Step Mother
- ☐ Step Father
- ☐ Brother(s) or Sister(s)
- ☐ Grandparent(s)
- ☐ Other Relative(s)
- ☐ Friend(s)
- ☐ Legal Guardian(s)
- ☐ OTHER

8. What is the **COMBINED** annual income for your household (before taxes)?

- ☐ Less than £10,000
- ☐ £10,000 - £19,999
- ☐ £20,000 - £29,999
- ☐ £30,000 - £39,999
- ☐ £40,000 - £49,999
- ☐ £50,000 - £59,999
- ☐ £60,000 - £69,999
- ☐ £70,000 - £79,999
- ☐ £80,000 - £89,999
- ☐ 90,000 and above

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9. How many functioning motorised vehicles (car, truck, motorcycle, moped, etc) are available for use at your house?

- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5 or more

10. How many television sets are in your household?

- ☐ 0
- ☐ 1
- ☐ 2
- ☐ 3
- ☐ 4
- ☐ 5 or more

11. What best describes your type of television service for the primary television in the house?

- ☐ No television
- ☐ Antenna only
- ☐ Basic cable
- ☐ Cable + premium channel(s)
- ☐ Satellite dish
- ☐ Other
- ☐ Don't know

12. What best describes your type of internet service?

- ☐ No internet access
- ☐ Dial-up modem
- ☐ Broadband
- ☐ Cable modem
- ☐ Other
- ☐ Don't know

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Questionnaire administered by: Interviewer ☐ Self-administered ☐

13. What is the **MOTHER'S** highest level of education completed?

- ☐ Less than secondary school
- ☐ Some secondary school
- ☐ GCSE or equivalent
- ☐ A level or equivalent
- ☐ Bachelor's degree
- ☐ Graduate/professional degree

14. How many hours per week does the **MOTHER** work outside the home?

- ☐ None
- ☐ Less than 15 hours/week
- ☐ Part-time (15-35 hours per week)
- ☐ Full time (36+ hours per week)

15. What is the **FATHER'S** highest level of education completed?

- ☐ Less than secondary school
- ☐ Some secondary school
- ☐ GCSE or equivalent
- ☐ A level or equivalent
- ☐ Bachelor's degree
- ☐ Graduate/professional degree

16. How many hours per week does the **FATHER** work outside the home?

- ☐ None
- ☐ Less than 15 hours/week
- ☐ Part-time (15-35 hours per week)
- ☐ Full time (36+ hours per week)

17. Is this child adopted? ☐ Yes ☐ No

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18. Please answer the following questions with regard to the child's **BIOLOGICAL MOTHER**:

Current Height: _____ ft and inches (or_____ cm)

Weight: ____stones and lbs (or_____kg)

Current Age: _____ years

Age at child's birth: ____ years

☐ Biological Mother's information cannot be estimated or is not known

19. Please answer the following questions with regard to the child's **BIOLOGICAL FATHER:**

Current Height: _____ ft and inches (or_____ cm)

Weight: _____stones and lbs (or_____ kg)

Current Age: _____ years

☐ Biological Father's information cannot be estimated or is not known

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Appendix 3: ISCOLE Neighbourhood & Home Environment Questionnaire

Where "child" is mentioned, please respond only about the child who is participating in this study. Be as accurate as you can. There are no right or wrong answers. All information is strictly confidential.

A. NEIGHBOURHOOD COHESION

Do you agree or disagree with the following statements?	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree
1. People around my neighbourhood are willing to help their neighbours.	○	○	○	○	○
2. This is a close-knit neighbourhood.	○	○	○	○	○
3. People in my neighbourhood can be trusted.	○	○	○	○	○
4. People in my neighbourhood generally <u>don't</u> get along with each other.	○	○	○	○	○
5. People in my neighbourhood <u>do not</u> share the same values, attitudes or beliefs.	○	○	○	○	○

B. NEIGHBOURS AND FRIENDS

1. Think about the neighbourhood or area in which you live. In general, how well do you feel you know your neighbours?

Not at all	Just a little	Moderately well	Extremely well
○	○	○	○

2. About how often do you talk to or visit your immediate neighbours (people in the 10-20 households that live closest to you)?

Never	Once a year or less	Several times a year	Once a month	Several times a month	Several times a week	Almost every day
○	○	○	○	○	○	○

C. NEIGHBOURHOOD RESPONSE

For the following statements, please mark how likely a neighbour would respond to, or take action in the following situations:	Very unlikely	Unlikely	Neither likely nor unlikely	Likely	Very likely
1. If a group of neighbourhood children were skipping school and hanging out on a street corner, how likely is it that your neighbours would do something about it?	○	○	○	○	○
2. If some children were spray-painting graffiti on a local building, how likely is it that your neighbours would do something about it?	○	○	○	○	○

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For the following statements, please mark how likely a neighbour would respond to, or take action in the following situations:	Very unlikely	Unlikely	Neither likely nor unlikely	Likely	Very likely
3. If a child was showing disrespect to an adult, how likely is it that people in your neighbourhood would scold that child?	○	○	○	○	○
4. If there was a fight in front of your house and someone was being beaten or threatened, how likely is it that your neighbours would break it up?	○	○	○	○	○
5. Suppose that because of budget cuts the fire station closest to your home was going to be closed down by the city. How likely is it that neighbourhood residents would organize to try to do something to keep the fire station open?	○	○	○	○	○

D. FOODS IN THE HOME

How often are the following foods/drinks available in your home?	Never	Rarely	Sometimes	Often	Always
1. Chocolate bars	○	○	○	○	○
2. Other sweets	○	○	○	○	○
3. Raw fruit (e.g., apples, oranges)	○	○	○	○	○
4. Cakes, brownies, muffins or cookies	○	○	○	○	○
5. Regular crisps or crackers	○	○	○	○	○
6. Baked crisps, low-fat crackers, pretzels	○	○	○	○	○
7. Raw vegetables (e.g., carrots)	○	○	○	○	○
8. 100% fruit juice	○	○	○	○	○
9. Juice drinks (e.g., Sunny Delight, Fruit Shoots)	○	○	○	○	○
10. Regular fizzy drinks with sugar	○	○	○	○	○
11. Diet or sugar free fizzy drinks	○	○	○	○	○
12. Sports drinks (e.g., Lucozade)	○	○	○	○	○
13. Fruit roll-ups or other dried fruit	○	○	○	○	○
14. Whole or full-fat milk	○	○	○	○	○
15. Skimmed or semi-skimmed milk	○	○	○	○	○
16. Sweetened breakfast cereal	○	○	○	○	○
17. Unsweetened breakfast cereal	○	○	○	○	○

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E. WHERE YOU SHOP

When you, or the main food shopper in your home, go food shopping, how often do you go to each of these types of shops?	Never	Rarely	Sometimes	Often	Always
1. Large supermarket or discount warehouse	○	○	○	○	○
2. Small to medium supermarket	○	○	○	○	○
3. Convenience store	○	○	○	○	○
4. Farmer's market/produce stand	○	○	○	○	○
5. Other, specify: _____	○	○	○	○	○

F. ACCESS TO SHOPS

Please indicate whether the following statements are true of the shop <u>where you usually buy groceries</u>.	Yes	No	Not applicable
1. Close to location of my employment	○	○	○
2. Close to my child's school	○	○	○
3. Close to my home	○	○	○

G. FOOD SHOPPING

The following questions apply to the shop <u>where you usually buy groceries</u>.	Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree
1. Low-fat foods cost too much.	○	○	○	○	○
2. There is a large selection of fresh fruits and vegetables.	○	○	○	○	○
3. There is a large selection of low-fat products available.	○	○	○	○	○
4. The condition of fresh fruits and vegetables is poor.	○	○	○	○	○
5. Fruits and vegetables cost too much.	○	○	○	○	○

H. YOUR CHILD'S ELECTRONICS

Please indicate whether the following are <u>in your child's bedroom</u>.	Yes	No
1. TV	○	○
2. Computer	○	○
3. Video game system (non-hand held; Playstation, Xbox, etc.)	○	○

Does your child have the following items for his/her own use?		
4. Mobile phone or 2-way radio (walkie-talkie)	○	○
5. Hand-held videogame players (Game Boy, Sony PSP, DS, etc.)	○	○
6. Music systems (Ipod, stereo, radio, etc.)	○	○

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For the next two questions, please think about your child's activities over the *past year*.

I. PLAY EQUIPMENT

How often during the past year has your child used these items at or around home (or in a common apartment area)?	Not available (Don't have)	Available but never use	Once a month or less	Once every other week	Once a week or more
1. Bike	○	○	○	○	○
2. Basketball hoop	○	○	○	○	○
3. Skipping rope	○	○	○	○	○
4. Active video games (e.g., with dance pad, Wii, etc)	○	○	○	○	○
5. Sports equipment (like ball, racquets, bats, sticks)	○	○	○	○	○
6. Swimming pool	○	○	○	○	○
7. Roller skates, skateboard, scooter	○	○	○	○	○
8. Fixed play equipment (e.g., swing set, playhouse, jungle gym)	○	○	○	○	○

J. PLACES FOR YOUR CHILD'S PHYSICAL ACTIVITY

How often during the past year has your child been <u>physically active</u> (including active play) in the following places?	Never	Once a month or less	Once every other week	Once a week	2 or 3 times/ week	4 times/ week or more
1. Inside your home	○	○	○	○	○	○
2. In your garden or common area or in your driveway	○	○	○	○	○	○
3. At a neighbour's house, garden, or driveway	○	○	○	○	○	○
4. In a local street, pavement, or wasteground	○	○	○	○	○	○
5. Indoor recreation or exercise facility (public or private; e.g., YMCA/Leisure centre)	○	○	○	○	○	○
6. Beach, lake, river, or stream	○	○	○	○	○	○
7. Bike/hiking/walking trails, paths	○	○	○	○	○	○
8. Basketball court	○	○	○	○	○	○
9. Other playing fields/courts (like football, softball, tennis)	○	○	○	○	○	○
10. Small public park or playground	○	○	○	○	○	○
11. Large public park	○	○	○	○	○	○
12. Public open space that is not a park	○	○	○	○	○	○
13. School grounds (during non-school hours)	○	○	○	○	○	○

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K. GETTING AROUND IN YOUR NEIGHBOURHOOD

Please select the answer that best applies to you and your neighbourhood. Within walking distance means within a 10-15 minute walk from your home.

	Strongly disagree	Somewhat disagree	Somewhat agree	Strongly agree
1. There are shops, stores, markets, and places to buy things I need within easy walking distance of my home/house.	○	○	○	○
2. There is a bus or train stop within walking distance from my home.	○	○	○	○
3. There are pavements on most streets.	○	○	○	○
4. There are NOT many dead end streets.	○	○	○	○
5. There are many different routes for getting from place to place.	○	○	○	○
6. There is a high crime rate.	○	○	○	○
7. The speed of traffic on most streets is usually slow (30 mph or less).	○	○	○	○
8. Most drivers go faster than the posted speed limits.	○	○	○	○
9. There are many interesting things to look at while walking in my neighbourhood.	○	○	○	○
10. The traffic makes it difficult or unpleasant for my child to walk.	○	○	○	○
11. Streets have good lighting at night.	○	○	○	○
12. There are pedestrian crossings and lights on busy streets.	○	○	○	○
13. There are many places to go within easy walking distance of my home.	○	○	○	○
14. I'm afraid of my child being taken or hurt by a stranger on local streets.	○	○	○	○
15. I'm afraid of my child being taken or hurt by a stranger in my garden, driveway, or common area.	○	○	○	○
16. I'm afraid of my child being taken or hurt by a stranger in a local park.	○	○	○	○
17. I'm afraid of my child being taken or hurt by a known "bad" person (adult or child) in my neighbourhood.	○	○	○	○

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(attach label here)

Technician Initials ☐☐☐

Date ☐☐ / ☐☐☐ / ☐☐☐☐

Questionnaire administered by: Interviewer ☐ Self-administered ☐

L. DISTANCE TO LOCATIONS

About how long would it take <u>you</u> to walk from your home to the nearest places listed below? Please select the time it would take you to walk to each place, regardless of whether you/your child go there.

	1-5 min	6-10 min	11-20 min	21-30 min	31+ min	Don't know
1. Convenience/corner shop/small grocery shop/off licence	○	○	○	○	○	○
2. Supermarket	○	○	○	○	○	○
3. Fast food restaurant	○	○	○	○	○	○
4. Non-fast food restaurant	○	○	○	○	○	○
5. Indoor recreation or exercise facility (public or private; e.g., YMCA/Leisure centre)	○	○	○	○	○	○
6. Beach, lake, river, or stream	○	○	○	○	○	○
7. Bike/hiking/walking trails, paths	○	○	○	○	○	○
8. Basketball court (including half-court)	○	○	○	○	○	○
9. Other playing fields/courts (like football, tennis, cricket, skate park, etc.)	○	○	○	○	○	○
10. Small public park	○	○	○	○	○	○
11. Large public park	○	○	○	○	○	○
12. Public playground with equipment	○	○	○	○	○	○
13. School with recreation facilities open to the public	○	○	○	○	○	○

M. FAMILY

During a typical week, how often do you or another adult in the household:

	Never	1-2 days	3-4 days	5-6 days	Everyday
1. Watch your child participate in physical activity or sports	○	○	○	○	○
2. Encourage your child to do sports or physical activity	○	○	○	○	○
3. Provide transport to a place where your child can do physical activity or play sports	○	○	○	○	○
4. Do a physical activity or play sports with your child	○	○	○	○	○

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Appendix 4: ISCOLE School Environment Questionnaire

A. SCHOOL CHARACTERISTICS

1. What is your position at this school? ☐ Head teacher ☐ Deputy head teacher ☐ Teacher ☐ Other

2. What is the total number of students in your school? (Please estimate) _____ students

3. What is the total number of teachers (full time equivalents) in your school? (Please estimate) _____ teachers

4. What grades/year-groups are taught at your school? _____ to _____

5. How many days (excluding holidays) do your students attend school during the academic school year? _____

B. POLICIES AND PRACTICES

For the following section, "policies" refers to any mandates issued by the district, local authorities, or any other agency, including policies developed by your school or (district/diocese), that affects your school environment and that have been officially adopted by your school or district. This section also asks about practices (what your students and staff are allowed to do on a regular basis) that you might follow to promote the health and well-being of students.

6. Does your school have written policies or practices concerning physical activity?

- ☐ **Yes**, existing written policies
- ☐ **Yes**, written policies still under development
- ☐ **Yes,** practices
- ☐ No
- ☐ N/A

7. Does your school have written policies or practices concerning healthy eating?

- ☐ **Yes**, existing written policies
- ☐ **Yes**, written policies still under development
- ☐ **Yes,** practices
- ☐ No
- ☐ N/A

8. Does your school have a committee that oversees or offers guidance on the development of policies and practices concerning physical activity and healthy eating at your school (e.g., healthy schools team, school health or wellness council)?

- ☐ **Yes**, both physical activity and healthy eating
- ☐ **Yes**, physical activity only
- ☐ **Yes,** healthy eating only
- ☐ No

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Questionnaire administered by: Interviewer ☐ Self-administered ☐

C. PHYSICAL ACTIVITY

9. What percent of students participate in the following extracurricular activities offered by your school?

(Please estimate)

	Not available	*Less than 10%*	*10-24%*	*25-49%*	*50%+*
a. Interschool sports	☐	☐	☐	☐	☐
b. School sports or physical activity clubs (including dance)	☐	☐	☐	☐	☐
c. Academic/hobby clubs (e.g., chess, astronomy)	☐	☐	☐	☐	☐
d. Arts-based clubs (e.g., drama, music, photography)	☐	☐	☐	☐	☐

10. Does your school offer late bus/transportation service to students who participate in extra-curricular activities?

Yes ☐ No ☐

11. From the following list, please indicate which sports are offered in your interschool or school sports clubs/programs available to students in grade Year 6:

a. Not applicable, school does not offer interschool or school sports clubs to students in Year 6 ☐

	Interschool	*School sports clubs*		*Interschool*	*School sports clubs*
b. Basketball	☐	☐	j. Gymnastics	☐	☐
c. Volleyball	☐	☐	k. Wrestling	☐	☐
d. Netball	☐	☐	l. Athletics	☐	☐
e. Football	☐	☐	m. Badminton	☐	☐
f. Rounders	☐	☐	n. Swimming	☐	☐
g. Rugby	☐	☐	o. Cricket	☐	☐
h. Hockey	☐	☐	p. Ultimate Frisbee	☐	☐
i. Lacrosse	☐	☐	q. Other	☐	☐

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Questionnaire administered by: Interviewer ☐ Self-administered ☐

For the following questions, please consider students in Year 6 when answering.

12. How many breaks of 15 to 29 minutes do students in Year 6 have in a day?

☐ zero ☐ 1 ☐ 2 ☐ 3 or more

13. How many breaks of 30 minutes or more do students in Year 6 have in a day?

☐ zero ☐ 1 ☐ 2 ☐ 3 or more

14. How much class time is mandated to be allotted to physical education (PE)/Daily Physical Activity (DPA) for students in Year 6?

_____ **minutes per** *[check the box indicating the time unit]* **week** ☐ **day** ☐

☐ No specific amount is mandated

15. Compared to the class time allotted to physical education (PE)/Daily Physical Activity (DPA) for Year 6 as mandated by the National Curriculum, do students in Year 6 in your school receive on average:

☐ Less than the mandated amount
☐ Approximately the mandated amount
☐ More than the mandated amount
☐ No specific amount is mandated

16. To the best of your knowledge, how well do each of the following statements characterize your school?

	A lot	*Some*	*Very little*	*Not at all*	*Don't know*
a. We use physical activity as a reward	☐	☐	☐	☐	☐
b. We promote physical activity during or as part of special events	☐	☐	☐	☐	☐
c. We integrate physical activity into other curriculum areas	☐	☐	☐	☐	☐
d. We use physical activity as a punishment for bad behavior (e.g., withholding break, administering push-ups or laps).	☐	☐	☐	☐	☐

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Questionnaire administered by: Interviewer ☐ Self-administered ☐

17. Does your school promote *active transportation* to and from school in any of the following ways?

	Yes	*No*	*Don't know*
a. Identify safe routes to use for walking and cycling to and from school (e.g., with signs, in newsletters, etc.)	☐	☐	☐
b. Provide crossing guards at intersections to encourage safe walk-to-school routes	☐	☐	☐
c. Designate a 'car free zone' to provide safe walking areas around the school	☐	☐	☐
d. Allow students to bring bicycles on school property	☐	☐	☐
e. Allow students to bring small wheel vehicles (e.g., rollerblades, scooters, skateboards) on school property	☐	☐	☐
f. Encourage the use of helmets and safety gear for those who use bicycles and small wheel vehicles to get to school	☐	☐	☐
g. Organize occasional 'walk to school days' , walking clubs, or programs like 'walking school buses' (where parents or older students walk around the neighborhood and pick up walkers at designated points)	☐	☐	☐

D. SCHOOL FACILITIES

18. Do the majority of students at your school have regular access to any of the following during school hours*? *During school hours means from the first bell to the last bell, including both instructional and non-instructional time (e.g., lunch).

	Yes, on grounds only	*Yes, off grounds only*	*Yes, both on and off grounds*	*No*	*Don't know*
a. Gymnasium	☐	☐	☐	☐	☐
b. Other large room suitable for physical activity (e.g., auditorium, cafeteria, dance studio)	☐	☐	☐	☐	☐
c. Fitness room for aerobic and/or strength training	☐	☐	☐	☐	☐
d. Running track	☐	☐	☐	☐	☐
e. Outdoor sports field (e.g., football or rugby)	☐	☐	☐	☐	☐
f. Outdoor paved area (e.g., tennis courts, basketball courts, any paved area that can be used for active games like skipping or hopscotch)	☐	☐	☐	☐	☐
g. Ice skating rink/arena	☐	☐	☐	☐	☐
h. Indoor swimming pool	☐	☐	☐	☐	☐
i. Secure changing room lockers available for use during physical activity	☐	☐	☐	☐	☐

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(attach label here)

Technician Initials ☐☐☐

Date ☐☐ / ☐☐☐ / ☐☐☐☐

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j. Changing rooms available for use before and after physical activity	☐	☐	☐	☐	☐
k. Showers available for use before or after physical activity	☐	☐	☐	☐	☐
l. Bicycle racks	☐	☐	☐	☐	☐
m. **If yes**, are the racks in a secure area to avoid theft?	☐	☐	☐	☐	☐
n. Grassy playground area	☐	☐	☐	☐	☐
o. Playground equipment (e.g., climbing structures, swings)	☐	☐	☐	☐	☐
p. Art room	☐	☐	☐	☐	☐
q. Music room	☐	☐	☐	☐	☐

19. Do students have access to the following facilities where they can buy foods or drinks?

	Yes	*No*
a. Cafeteria	☐	☐
b. School shop	☐	☐
c. Shops/fast food restaurants close to school	☐	☐
d. Sweet and crisps vending machine	☐	☐
e. Drinks vending machine (e.g., coke, soft drinks, orange juice)	☐	☐
f. Milk vending machine (e.g., milk, chocolate milk)	☐	☐

20. *Outside of school hours*,* does your school permit regular student access to the following?

**Outside of school hours means before and/or after school, evenings and weekends. Student access may occur via school-led, community-led or informal use.*

	Yes	*No*	*Don't know*	*N/A*
a. Gymnasium	☐	☐	☐	☐
b. Indoor facilities	☐	☐	☐	☐
c. Outdoor facilities (e.g., playing fields, paved activity areas, baseball diamond)	☐	☐	☐	☐
d. Equipment (e.g., basketballs)	☐	☐	☐	☐

21. *Outside of school hours*,* does your school allow community groups to use the school facilities?

**Outside of school hours means before and/or after school, evenings and weekends.*

Yes ☐ No ☐ Don't know ☐

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Questionnaire administered by: Interviewer ☐ Self-administered ☐

E. HEALTHY EATING

22. Does your school provide any of the following to promote the sale of healthy food? (Check all that apply)

	Cafeteria	*Snack bar/ School shop*	*Vending machine(s)*
a. Healthy food choices at a reasonable/subsidized price	☐	☐	☐
b. Healthy eating promotional materials (e.g., posters)	☐	☐	☐
c. Daily healthy eating specials	☐	☐	☐
d. Healthy eating cafeteria program (e.g., our school food)	☐	☐	☐

23. Does your school ensure that all students, regardless of ability to pay, have access to fruits and vegetables?

☐ Yes, entire school year
☐ Yes, occasional/short term
☐ No

24. Does your school offer any of the following? (Check all that apply)

☐ Cooking classes
☐ Gardening (e.g., growing produce)
☐ Field trips to farms/farmers' markets
☐ Media literacy on special topics related to healthy eating (e.g., body image, eating disorders)
☐ Field trips to the local greengrocers

25. During the past 12 months, did your school initiate/continue any of the following activities/programs at your school?

	Yes	*No*	*N/A*
a. Offered healthy food choices during breakfast programme	☐	☐	☐
b. Offered healthy food choices during lunch programme	☐	☐	☐
c. Offered healthy food choices in the cafeteria(s)	☐	☐	☐
d. Offered healthy food choices in the snack bar/school shop(s)	☐	☐	☐
e. Offered healthy food choices in the vending machine(s)	☐	☐	☐
f. Organized activities for healthy eating week or equivalent	☐	☐	☐
g. Stopped the sale of junk food	☐	☐	☐
h. Held junk food free days	☐	☐	☐
i. Stopped the sale of sugar-sweetened beverages	☐	☐	☐

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Questionnaire administered by: Interviewer ☐ Self-administered ☐

26. During the past 12 months, have any of the following items been sold as part of fundraising for any school organization?

	Yes	*No*	*N/A*
a. Chocolate	☐	☐	☐
b. Other sweets	☐	☐	☐
c. Other junk food (e.g., popcorn)	☐	☐	☐
d. Fizzy pop or fruit drinks that are not 100% juice	☐	☐	☐
e. Sports drinks	☐	☐	☐
f. Biscuits, cookies, crackers, cakes, pastries, or other baked goods that are not low in fat	☐	☐	☐
g. Fruits or vegetables	☐	☐	☐
h. 100% fruit juice or vegetable juice	☐	☐	☐
i. Low-fat biscuits, cookies, crackers, cakes, pastries, or other low-fat baked goods	☐	☐	☐

F. NEIGHBOURHOOD/COMMUNITY

27. How much of a problem are the following in the neighbourhood where this school is located?

	Major problem	*Moderate problem*	*Minor problem*	*Not a problem*	*I don't know*
a. Tensions based on racial, ethnic, or religious differences	☐	☐	☐	☐	☐
b. Litter, rubbish, or broken glass in the street or road, on the pavements or in gardens	☐	☐	☐	☐	☐
c. Selling or using drugs or excessive drinking in public	☐	☐	☐	☐	☐
d. Gangs	☐	☐	☐	☐	☐
e. Heavy traffic	☐	☐	☐	☐	☐
f. Vacant or shabby houses and buildings	☐	☐	☐	☐	☐
g. Crime in the neighbourhood	☐	☐	☐	☐	☐

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Appendix 5: Sensitivity Analysis for Chapter 2

Results from the sensitivity analysis conducted in Chapter 2 are displayed below. The main analysis was repeated using the Treuth MVPA cut-points (with the original WHO criteria for overweight/obesity; Table 1), and using the CDC and IOTF criteria for overweight/obesity (with the original Evenson MVPA cut-points; Table 2).

Table 1. Odds associated with being overweight/obese in relation to multiple lifestyle behaviours, using the Treuth MVPA cut-points: ORs* and 95% CIs.

	Model 1†	**Model 2**
MVPA (min/day)	0.69 (0.52 to 0.91)	0.67 (0.50 to 0.89)
p value	*0.009*	*0.006*
Sleep duration (min/night)	-	0.66 (0.51 to 0.85)
p value		*0.001*
Screen time score	-	1.52 (1.12 to 2.05)
p value		*0.007*
Healthy diet score	-	1.33 (1.03 to 1.72)
p value		*0.028*
Unhealthy diet score	-	1.00 (0.77 to 1.30)
p value		0.993

Italic font indicates significant results.

*Odds ratios are expressed per standard deviation increase in each variable (MVPA = 18, sleep duration = 43; screen time = 2; healthy diet score = 1; unhealthy diet score = 1).

Model 1: Adjusting for age, sex and SES (parental education level) with schools treated as random effects.

Model 2: All independent variables entered simultaneously in a mutually adjusted model, with covariates. Schools were treated as random effects.

p values are from Type 3 Tests of Fixed Effects.

MVPA, moderate-to-vigorous intensity physical activity; SES, socioeconomic status.

Table 2. Odds associated with being overweight/obese using the CDC and IOTF criteria, in relation to multiple lifestyle behaviours: ORs* and 95% CIs.

	CDC Criteria		IOTF Criteria	
	Model 1	**Model 2**	**Model 1**	**Model 2**
MVPA (min/day)	0.60 (0.43 to 0.84)	0.54 (0.38 to 0.76)	0.60 (0.43-0.84)	0.53 (0.37 to 0.77)
p value	*0.003*	*0.001*	*0.003*	*0.001*
Sleep duration (min/night)	0.65 (0.49-0.85)	0.62 (0.46 to 0.82)	0.64 (0.48 to 0.85)	0.61 (0.46 to 0.82)
p value	*0.002*	*0.001*	*0.002*	*0.001*
Screen time score	1.30 (0.96 to 1.77)	1.29 (0.91 to 1.82)	1.23 (0.90 to 1.70)	1.20 (0.84 to 1.72)
p value	0.090	0.147	0.195	0.309
Healthy diet score	1.25 (0.95 to 1.66)	1.34 (1.00 to 1.79)	1.17 (0.88 to 1.55)	1.24 (0.92 to 1.66)
p value	0.114	0.052	0.283	0.161
Unhealthy diet score	1.16 (0.90 to 1.49)	1.08 (0.81 to 1.45)	1.14 (0.88 to 1.48)	1.09 (0.81 to 1.48)
p value	0.251	0.605	0.327	0.565

Italic font indicates significant results.

*Odds ratios are expressed per standard deviation increase in each variable (MVPA = 23, sleep duration = 43; screen time = 2; healthy diet score = 1; unhealthy diet score = 1).

Model 1: Adjusting for age, sex and SES (parental education level) with schools treated as random effects.

Model 2: All independent variables entered simultaneously in a mutually adjusted model, with covariates. Schools were treated as random effects.

p values are from Type 3 Tests of Fixed Effects.

CDC, Centers for Disease Control and Prevention; IOTF, International Obesity Task Force; MVPA, moderate-to-vigorous intensity physical activity; SES, socioeconomic status

Appendix 6: Chapter 7 Closing Commentary UK-specific Results

Table 1. Relationships between screen-based behaviours and physical activity outcomes, by sex in the UK sample (n=430): lsmeans (95% CIs).

		TV viewing				Computer games			
		Low	Medium	High	*p*	None	Medium	High	*p*
Boys (n=187)	**LPA**								
	Overall	284.8 (273.2-296.5)	291.1 (277.3-305.0)	290.7 (274.1-307.4)	.572	309.5 (282.6-336.4)	289.4 (278.1-300.8)	279.4 (265.8-293.1)	.061
	After school	123.3 (117.0-129.5)	123.9 (116.8-131.0)	125.5 (117.1-134.0)	.858	130.2 (121.2-139.2)	124.5 (118.3-130.7)	120.0 (113.1-126.9)	.084
	Weekend	260.4 (243.9-276.9)	275.2 (261.1-289.3)	289.4 (270.1-308.8)[a]	**.029**	281.7 (254.9-308.5)	285.1 (268.1-302.0)	265.2 (250.4-280.1)	.052
	MVPA								
	Overall	74.3 (68.0-80.6)	70.9 (63.3-78.6)	84.3 (74.9-93.6)[b]	**.032**	84.8 (69.0-100.6)	75.9 (69.6-82.3)	70.9 (63.2-78.6)	.163
	After school	35.6 (31.3-40.0)	32.5 (27.5-37.5)	39.5 (33.5-45.6)	.101	42.8 (36.3-49.3)	33.6 (29.3-38.0)[c]	34.8 (29.9-39.7)	**.020**
	Weekend	69.8 (59.9-79.6)	62.4 (54.2-70.7)	78.4 (66.7-90.0)[b]	**.035**	80.9 (64.8-97.0)	69.9 (60.3-79.5)	64.3 (56.2-72.4)	.120
Girls (n=243)	**LPA**								
	Overall	284.3 (272.2-296.5)	285.1 (271.2-299.1)	283.8 (265.8-301.8)	.986	286.8 (270.2-303.4)	285.0 (273.2-296.8)	279.3 (262.2-296.4)	.705
	After school	130.9 (125.4-136.4)	130.7 (124.3-137.2)	130.5 (121.8-139.3)	.997	133.0 (126.3-139.7)	129.8 (124.3-135.3)	129.9 (121.8-138.1)	.630
	Weekend	280.6 (263.2-298.1)	281.7 (266.8-296.6)	275.5 (254.7-296.4)	.829	283.7 (263.6-303.8)	283.1 (268.1-298.0)	273.1 (255.9-290.4)	.427
	MVPA								
	Overall	57.6 (53.8-61.5)	57.7 (53.0-62.5)	52.1 (45.3-59.0)	.281	59.5 (53.3-65.8)	56.3 (52.6-60.1)	57.3 (50.8-63.8)	.592
	After school	29.0 (26.4-31.6)	29.4 (26.4-32.4)	28.2 (24.1-32.3)	.869	28.1 (25.0-31.2)	28.9 (26.3-31.4)	31.1 (27.2-34.9)	.398
	Weekend	55.7 (49.0-62.4)	48.7 (43.5-53.9)	41.4 (33.0-49.7)[a]	**.018**	51.1 (43.0-59.3)	49.4 (44.0-54.8)	48.6 (42.0-55.2)	.873

Results are presented as least squares means, showing the relationships between school day TV/computer and after school physical activity; weekend TV/computer and weekend physical activity; overall TV/computer and overall physical activity. All models are adjusted for age, SES (highest parental education level), BMI z-score, and accelerometer wear time. Schools were treated as random effects. Overall and School day TV viewing categories: Low = < 2 h/d; Medium = 2-3 h/d; High = ≥ 3 h/d; weekend TV viewing categories: Low = < 2 h/d; Medium = 2-4 h/d; High = ≥ 4 h/d; Computer games categories: None = 0 h/d; Medium = < 2 h/d; High = ≥ 2 h/d.

Bold font indicates significant relationship ($p<0.05$); p values taken from type 3 tests of fixed effects.

[a] = Significant difference between 'high' and 'none'/'low' groups for computer/TV; [b] = Significant difference between 'high' versus 'medium' groups; [c] = significant difference between 'medium' vs. 'none'/'low' groups for computer/TV. All taken from Bonferroni adjusted p values.

BMI, body mass index; LPA, light intensity physical activity; MVPA, moderate-to-vigorous intensity physical activity; SES, socioeconomic status; TV, television.

Table 2. Relationships between screen-based behaviours and physical activity outcomes, by SES in the UK sample (n=430): lsmeans (95% CIs).

		TV viewing				Computer games			
		Low	**Medium**	**High**	***p***	**None**	**Medium**	**High**	***p***
Low SES (n=122)	**LPA**								
	Overall	282.1 (266.4-297.8)	289.2 (271.7-306.6)	308.3 (286.0-330.6)[a]	**.042**	283.0 (259.4-306.6)	293.7 (278.8-308.7)	272.8 (253.6-292.0)[b]	**.038**
	After school	130.3 (121.8-138.8)	131.5 (122.1-140.9)	141.9 (129.9-153.9)	.146	133.1 (121.9-144.3)	136.6 (128.4-144.8)	125.0 (114.7-135.2)	.079
	Weekend	258.0 (237.1-278.9)	284.0 (268.6-299.5)	292.2 (267.6-316.7)	**.048**	270.0 (242.9-297.1)	290.7 (272.8-308.6)	271.3 (254.2-288.5)	.188
	MVPA								
	Overall	65.4 (58.7-72.1)	67.5 (59.5-75.4)	71.9 (60.4-83.4)	.565	63.6 (51.0-76.2)	67.7 (61.5-73.8)	66.7 (57.4-76.0)	.813
	After school	32.8 (27.7-37.8)	33.4 (27.8-39.1)	39.5 (32.0-47.0)	.224	29.5 (22.5-36.5)	34.5 (29.6-39.4)	36.6 (30.3-42.9)	.253
	Weekend	60.3 (48.6-71.9)	53.9 (45.0-62.8)	60.6 (47.0-74.2)	.518	58.8 (44.0-73.5)	59.5 (49.6-69.5)	53.9 (44.2-63.5)	.645
High SES (n=308)	**LPA**								
	Overall	285.5 (275.6-295.3)	284.9 (273.1-296.7)	276.6 (262.1-291.0)	.413	298.2 (281.5-314.9)	284.0 (274.4-293.6)	277.8 (265.0-290.5)	.086
	After school	124.1 (119.6-128.6)	123.8 (118.3-129.4)	119.9 (112.9-126.9)	.484	128.3 (122.2-134.3)	121.7 (117.2-126.2)	122.5 (116.5-128.5)	.106
	Weekend	279.7 (265.0-294.3)	277.5 (264.9-290.1)	273.2 (256.0-290.5)	.788	289.6 (270.1-309.1)	283.4 (270.1-296.6)	267.3 (253.6-280.9)[b]	**.021**
	MVPA								
	Overall	64.1 (59.9-68.3)	60.9 (55.8-66.0)	64.4 (58.0-70.8)	.389	72.4 (65.0-79.9)	63.0 (58.9-67.1)[c]	59.9 (54.3-65.5)[a]	**.011**
	After school	30.1 (27.6-32.5)	28.5 (25.4-31.5)	30.1 (26.3-33.8)	.572	33.1 (29.8-36.3)	28.2 (25.7-30.7)[c]	29.4 (26.2-32.7)	**.016**
	Weekend	62.9 (56.4-69.4)	56.0 (50.8-61.3)	56.9 (48.8-64.9)	.152	67.0 (57.7-76.3)	58.2 (52.6-63.9)	55.5 (49.6-61.4)	.081

Results are presented as least squares means, showing the relationships between school day TV/computer and after school physical activity; weekend TV/computer and weekend physical activity; overall TV/computer and overall physical activity. All models are adjusted for age, sex, BMI z-score, and accelerometer wear time. Schools were treated as random effects.
Overall and School day TV viewing categories: Low = < 2 h/d; Medium = 2-3 h/d; High = ≥ 3 h/d; weekend TV viewing categories: Low = < 2 h/d; Medium = 2-4 h/d; High = ≥ 4 h/d; Computer games categories: None = 0 h/d; Medium = < 2 h/d; High = ≥ 2 h/d.
Bold font indicates significant relationship (p<0.05); p values taken from type 3 tests of fixed effects.
[a] = Significant difference between 'high' and 'none'/'low' groups for computer/TV; [b] = Significant difference between 'high' versus 'medium' groups; [c] = significant difference between 'medium' vs. 'none'/'low' groups for computer/TV. All taken from Bonferroni adjusted p values.
BMI, body mass index; LPA, light intensity physical activity; MVPA, moderate-to-vigorous intensity physical activity; SES, socioeconomic status; TV, television.